AGRONOMY

PRACTICAL GARDENING FOR HIGH SCHOOLS

BY WILLARD N. CLUTE

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~~IN PRESS~~

This volume is unique in supplying the need of a book in agriculture for the high schools of towns and cities. All existing books are written with the needs of the farmer's boy and the country school in mind and are therefore not adapted to urban problems. This book shows the city child how to make the best of his lawn and garden and at the same time fits him to take up the more serious work of farming should his circumstances make this desirable.

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THIS book, designed especially for high-school students in cities and towns, gives a thorough grounding in the agricultural principles underlying the propagation, cultivation, and improvement of plants, and the fundamentals of decorative planting.

It begins with chapters on chemistry, the origin and composition of soils, manures, and the effects of heat, light, and moisture on the plant. These are followed by a comprehensive discussion of planting, cultivating, pruning, propagating, lawn making, plant breeding, evolution, and the origin of domestic races of plants. Insect pests and plant diseases are fully discussed and all known methods of control given. The book is unique in devoting much space to the improvement of the home grounds, both as regards the growing of better vegetables and the production of finer flowers and more tasteful lawns and borders.

Each chapter discusses the fundamentals of the subject and is followed by directions for laboratory and field work in which these principles find practical application. All the exercises outlined may be performed in the ordinary high school and do not require expensive apparatus. Their practicability has been established by the author in work with his own classes. Numerous references to the literature of the subject make further investigation by the student easy.

The work centers in the school garden and is planned to cover the second semester of the school year, following closely the sequence of the seasons. It is so arranged that a previous knowledge of botany is not essential, though the book is expected to be used to follow a half year's work in structural botany, and this arrangement forms an ideal introduction to other botanical courses.

It will also prove a valuable gardening manual for the general reader, since it covers the whole subject of gardening and requires no previous knowledge for its comprehension.

SCHOOL GARDENING ON A VACANT LOT

AGRONOMY

A COURSE IN PRACTICAL GARDENING FOR HIGH SCHOOLS

BY

WILLARD NELSON CLUTE

AUTHOR OF "LABORATORY BOTANY FOR HIGH SCHOOLS," "FLORA OF THE UPPER SUSQUEHANNA," "OUR FERNS IN THEIR HAUNTS," "FERN ALLIES OF NORTH AMERICA," ETC.

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PREFACE

This book has been prepared to meet the needs of high schools in cities and towns where agriculture is taught, and in which the problems that confront the teacher are in some respects different from those that come up in rural communities. The environment of the city child makes it undesirable to emphasize in his case the growing of stock, the production and care of milk, the breeding of animals, and the cultivation of field crops. There is, however, much information of a practical nature regarding the cultivation of plants which he finds necessary for the fullest enjoyment of his surroundings. Though not engaged in growing crops for a livelihood, he is, nevertheless, interested in the cultivation of vegetables and flowers, the making of lawns and their care, the planting of shrubbery, the trimming of trees, and similar matters. In the present volume it has been the aim, therefore, to develop the subject of agriculture from the urban viewpoint, though the matters discussed are fundamental to any system of cultivating plants and are as applicable to rural communities as elsewhere. Furthermore, it is expected that the book will also serve as a practical guide to that part of the general public which, though no longer in school, takes an interest in the cultivation of plants in lawn, garden, and orchard.

Agronomy, as outlined in the following pages, is regarded as a division of agriculture coördinate with animal husbandry. The latter division, though often included in books of this kind, is as distinct from agronomy as zoölogy is from botany, and has been omitted from this book partly because the subject of agronomy is alone sufficient for one semester's work,

and partly because city children are not brought much into contact with farm animals. Animal husbandry may well be taught as a separate course, and, if given in the semester following that in which agronomy is given, will afford the pupil a year's continuous work in agriculture. The practical nature of the matter here presented has been proved by several seasons' work with classes in a large city high school. No directions for work have been given that have not been tried out with such classes.

Agronomy differs from the usual botanical course of the high school in that it is largely the practice of an art rather than the study of a science. It seeks to make the student physically proficient as well as mentally alert. Although usually given after a course in botany, it is by nature an excellent introduction to the more technical study, since it enables the student to bring to bear upon it a considerable first-hand knowledge of plants and plant habits. In the high-school curriculum botany may be considered as existing for the sake of the drill it gives in observation and deduction, as well as for the information it affords, and it is therefore proper that it should be based largely upon experiment. In agronomy, however, experiment has a much smaller place. The fundamentals have so long been a matter of common knowledge that they need not be made the subjects for experiment, though the possibility of proving any phase of the work by this means should not be overlooked.

The course in agronomy here presented is designed to cover a half year of work in the laboratory and school garden and to be given in the spring semester. It is essentially an outdoor course in doing things, with the culture, propagation, and amelioration of plants as the central theme. It presupposes a school garden in which the pupil can carry out the work of cultivating and training plants, and the chief end of the course will be missed if this book is used merely as a

convenient source of material for recitations. Few schools are so situated as to make the possession of a school garden absolutely impossible. If the school grounds are not large enough, a vacant lot in the vicinity may be secured by rent or purchase, or the home garden of one of the pupils may be used. Some successfully managed school gardens are ten minutes' walk from the school building. Wherever located the garden ought to be securely fenced against the depredations of the small boy and other irresponsible folk, and a certain degree of permanency should be secured for the plantings, if possible, since at least part of the plants grown will be perennials, which improve with the years if left undisturbed. Whenever practicable, the school garden should be a part of the school property.

Classes seldom need to be encouraged to take an interest in gardening, but the teacher should see to it that the work is properly planned in advance, that time is allowed for cultivating the crops, and that such experiments are carried on in the experimental plots as will deepen the interest and value of the work to the student. The food, fiber, and drug plants little known in the region may be grown, the many varieties of common vegetables may be tested, and attractive flowers cultivated. Room should also be found for growing all sorts of aberrant plants that may be discovered by the class, such as those possessing double flowers, fasciated stems, color variations, and variations in the cutting of leaves. As a general thing, the crops planted should be such as mature before school closes for the summer or which do not mature until autumn. In the first group are lettuce, spinach, cress, radishes, onions, and turnips; in the second are carrots, parsnips, and salsify. The many forms of radishes now offered by seedsmen are excellent subjects for showing the great variation that may occur in a single plant part. A few experiments may be carried on for a series of years, especially such as

pertain to the training of special shrubs, trees, and vines, and the propagation or breeding of plants. The greatest success attends a class in which each pupil is allotted space for an individual garden, though two pupils may work in partnership with good results.

Every effort should be made to have the student secure first-hand information. A single visit to an implement store, for instance, will give him more information of real value than hours of recitation about implements which he has never seen or examined. For the same reason frequent field trips to parks, market gardens, nurseries, greenhouses, public gardens, and the like should be made. These trips should, if possible, be taken in the hours allotted to agronomy in the school day and should be counted as part of the regular work. In many cases the period for this study may come last in the day's program, thus allowing pupils to take as much additional time for the work after school as they desire. There is always a tendency on the part of the teacher to assume more knowledge of familiar things than the student possesses, and for this reason it is well to carry out all the exercises suggested, though at first glance some may appear too simple to be worth while.

To the end that the pupils be made conversant with the literature of the subject, they should be encouraged to consult the reference works named at the end of each chapter, as well as more general works such as Bailey's "Cyclopedia of American Horticulture" and "Cyclopedia of American Agriculture." Each student should also be encouraged to write to the national government for such publications on plants as may interest him. Upon application, the Superintendent of Documents, Government Printing Office, Washington, D. C., will send a list of publications to which a price is attached, and the Editor and Chief of the Division of Publications, Department of Agriculture, will send a monthly list of free

publications. In the case of the more expensive publications the pupil's representative in Congress or his senator may secure them free. The publications of his own state agricultural experiment station will also be most useful, and those of other states may often be obtained. All available pamphlets of the kind should, of course, be in the school library. It is often possible to secure enough duplicates of the more important publications to allow one for each member of the class. The pupils should also be supplied with the catalogues of reliable seedsmen and growers of nursery stock. These may usually be had upon request, and the writing of a letter for this purpose may well be made a part of the class work.

At the time the work in agronomy is begun the weather is not likely to be favorable for work in the open, but there are, fortunately, many matters of theory and fact that may be discussed in the classroom before the season for gardening begins, and some of the experiments may also be performed. The book has been arranged, as far as practicable, to follow the progress of the seasons, but in the early weeks of the course the theoretical may overshadow the practical, and matters may be discussed that will not be taken up in a practical way until much later. By looking ahead and selecting those exercises that may be performed as well at one time as at another, the student will be enabled to approach the real work of the course with considerable theoretical knowledge that can be tested later by practice.

One cannot deal intelligently with plants without knowing their names and relationships, and it is recommended that the identification of plants by the use of a good manual of botany be made part of the course. For this work the strictly technical manuals are better than the more popular volumes, since they not only give the names but teach exactness, increase the vocabulary, and familiarize the pupil with the use of scientific keys. The small preliminary instruction needed for the use of

such a manual may be given in the early part of the course, thus preparing the student to name the flowers as fast as they appear.

It is not easy to overestimate the value of all sorts of collections for use in connection with agronomy. The accumulation of striking objects with which to illustrate the course is, however, not a matter of a single year, for the specimens must be secured a few at a time as they are found. Soil maps, typical fungi, seed collections, samples of soils and fertilizers, mineral specimens and pictures of unusual crops, specimen plants, and unfamiliar farming operations all add to the attractiveness and interest of the course. If the school does not possess a museum in which these may be kept, they should be carefully preserved in the laboratory or classroom.

In most cases specific directions for performing an experiment or for carrying on the other work of the course have been omitted from this book, since the conditions in different schools are likely to vary, and the teacher will naturally prefer to work these out to fit his own local conditions. Indeed, in many instances, the planning of the work may be left to the student. No doubt mistakes will be made, but one may learn much from his mistakes. If the pupils have not had an earlier course in botany, or if it is desired to go deeper into the subject of the organization of the plant than is here presented, the author's "Laboratory Botany for the High School" may be found useful.

The sources of the illustrations in this volume are for the most part indicated in connection with the illustrations themselves, but the author takes this opportunity to acknowledge his indebtedness to the Bateman Manufacturing Company, Greenloch, New Jersey; Wagner's Park Conservatories, Sidney, Ohio; The Lord and Burnham Company, New York; and S. L. Allen, Philadelphia, for the loan of photographs and other material. Several illustrations that originally appeared

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AGRONOMY

CHAPTER I

A LESSON IN CHEMISTRY

Chemical elements. The earth's crust, the animals and plants upon it, and the multitude of substances with which we are familiar are composed of a small number of simpler forms of matter, known as *chemical elements*, combined in various ways. A chemical element may be defined as a substance that has not been resolved into simpler substances, and as thus defined there are only about eighty chemical elements in the world. Gold may be taken as an illustration. Though it be divided into particles too small to be visible in the microscope, or heated until it becomes liquid, or subjected to strong currents of electricity, it is still gold and nothing else. A few chemical elements may be found "native," that is, uncombined with others, but usually two or more unite to form *chemical compounds*. By far the larger number are always found thus combined. Oxygen may be cited as a familiar example of an element that exists both free and combined. As a free gas it forms about one fifth of the air we breathe; combined with other elements it makes up about half of the water and rock of the earth's crust. Chemical elements are often grouped as *metals* and *nonmetals*, the metals being greatly in the majority. Usually the metals may be distinguished by names ending in *um*. The difference between a metal and a nonmetal, however, is not easily defined. A metal is supposed to have the following properties: it must

exist as a solid and have a metallic luster, must be capable of conducting heat and electricity, must be opaque, hard, malleable, ductile, and capable of forming compounds with oxygen. Probably no single metal has all these properties, but no substance would be accepted as a metal that did not possess many of them. Iron, nickel, copper, and mercury are among the more familiar metals. Carbon, sulphur, and phosphorus may be named as examples of the nonmetals. Theoretically, at least, each chemical element may exist as a solid, a liquid, or a gas, but many have not yet been produced in all three of these conditions. Increasing the temperature will make many of the ordinary solids liquid, and the reverse of this process, combined with pressure, serves to liquefy even the lightest gases. Water, while not a chemical element, will serve to illustrate this change of state. In its more familiar form it is a liquid, but if heated to 212° F. it becomes a gas, and if cooled below 32° F. it becomes a solid.

Atoms and molecules. An *atom* is the smallest part of a chemical element that can enter into combination with other parts. Atoms may therefore be said to be the units of which more complex compounds are built. Not very much is known regarding the size of atoms, but they are estimated to be about one hundred-millionth of an inch in diameter and to bear about the same relation to the size of a tennis ball that the latter bears to the earth. Atoms usually do not long exist as such, but combine with other atoms to form *molecules*, which are the smallest enduring particles of a compound, just as the atoms are the smallest part of a chemical element. All the atoms of a single chemical element are exactly alike, otherwise it would not be a chemical element.

Chemical formulas. Atoms have the same relation to chemical compounds that letters have to words, and the chemist is therefore able to write a definite formula for the molecule of every substance. Each element has its own chemical symbol,

usually the initial of its name, as C for carbon and P for phosphorus. When the initial is duplicated in the list of symbols, one more distinguishing letter may be added, as Ca for calcium and Pt for platinum. Occasionally an element may be given the initial of an older name, as in the case of K for potassium, where the initial stands for *kalium.* Iron has the symbol Fe, derived from *ferrum.* The student familiar with the names of the elements readily recognizes the kinds of atoms that form a given compound when its formula is read. When more than one atom of a kind enters into the combination, the number is written below the line and immediately following the symbol. Thus the formula CO_2, representing a molecule of carbon dioxide, is seen to consist of one atom of carbon united with two atoms of oxygen. The molecule of water is written H_2O. In this two atoms of

TABLE OF THE MORE COMMON CHEMICAL ELEMENTS

NAME	SYMBOL	NAME	SYMBOL
Aluminum	Al	Lead (*plumbum*) . . .	Pb
Antimony (*stibium*) . .	Sb	Lithium	Li
Argon	A	Magnesium	Mg
Arsenic	As	Manganese	Mn
Barium	Ba	Mercury (*hydrargyrum*)	Hg
Bismuth	Bi	Nickel	Ni
Boron	B	Nitrogen	N
Bromine	Br	Oxygen	O
Calcium	Ca	Phosphorus	P
Carbon	C	Platinum	Pt
Chlorine	Cl	Potassium (*kalium*) . .	K
Cobalt	Co	Silicon	Si
Copper (*cuprum*) . . .	Cu	Silver (*argentum*) . .	Ag
Fluorine	F	Sodium (*natrium*) . .	Na
Gold (*aurum*)	Au	Sulphur	S
Hydrogen	H	Tin (*stannum*) . . .	Sn
Iodine	I	Tungsten (*wolfram*) .	W
Iron (*ferrum*)	Fe	Zinc	Zn

hydrogen are joined to one of oxygen. When symbols in parenthesis are followed by a number written below the line, as $Ca(NO_3)_2$, it signifies that the elements and quantities in parenthesis are to be multiplied by the number so written. Calcium phosphate ($Ca_3(PO_4)_2$) would also be correctly written $Ca_3P_2O_8$.

Chemical compounds. When salt and sand, or charcoal and sulphur, are stirred up together, the result is a mere mechanical mixture. In a chemical compound an entirely new substance is formed, which may possess characteristics quite unlike those of the combining elements. Under certain conditions charcoal and sulphur may be made to form a chemical union in which two atoms of sulphur join with one of carbon to produce carbon disulphide (CS_2). Sulphur, as everybody knows, is a yellow solid and carbon a black solid, but the carbon disulphide formed by their union is neither black, yellow, nor a solid, but is a colorless liquid resembling water. Moreover, while either pure carbon or sulphur may be eaten without harm, when they are chemically combined they form a deadly poisonous liquid, which, exposed to the air, soon turns to a heavy, suffocating, and highly inflammable gas. Again, when carbon is burned in the air, as in ordinary wood and coal fires, one atom of carbon unites with two of oxygen and forms a colorless, suffocating gas known as carbon dioxide (CO_2). In a similar way sulphur may be burned to form sulphur dioxide (SO_2). Calcium carbide, from which acetylene gas is produced, is another union of carbon and is represented by the formula CaC_2. It is interesting to note that all the chemical elements unite with others in definite and unvarying proportions. No matter how much oxygen may be present when carbon is burned, the molecule of carbon dioxide formed always consists of two atoms of oxygen and one of carbon. Carbon, however, may be made to form other combinations with oxygen. When there is a lack of oxygen, carbon monoxide (CO) may be

formed. Some elements, oxygen and carbon for instance, readily combine with a great many others, while some, like nitrogen and argon, are called inert, and only with difficulty can be made to unite with others. In chemical reactions heat is often evolved. A good illustration of this is seen in the heat that results from the union of oxygen and carbon when wood or coal is burned, or when water is added to quicklime in the process of making mortar.

Distribution of the elements. The different elements are very unequally distributed. Some, like radium, are found in very minute quantities and always in combination with other elements, while others may form vast deposits which are nearly pure. Only about forty of the elements are at all common, while but five of these form 96 per cent of the planet on which we live. These five in the order of their abundance are oxygen, silicon, aluminum, iron, and calcium. Since the soil consists of particles from many kinds of rocks, it contains a considerable number of chemical elements, but only sixteen that are at all abundant, namely, oxygen, silicon, carbon, sulphur, hydrogen, chlorine, phosphorus, fluorine, aluminum, calcium, magnesium, potassium, sodium, iron, manganese, and barium.

Elements found in plants. Fifteen of the sixteen common chemical elements in the soil are found in plants. Of these, seven are metals and eight are nonmetals. In the first group are potassium, sodium, magnesium, calcium, aluminum, iron, and manganese; in the second are oxygen, hydrogen, nitrogen, chlorine, carbon, phosphorus, sulphur, and silicon. Several of these are not regarded as essential to plant growth, as is also true of lithium, zinc, copper, boron, and fluorine, which are occasionally found in plants in certain regions. Some of the characteristics of the fifteen elements usually found in plants are given below.

Potassium (K) is a soft white metal, lighter than water. It quickly oxidizes or unites with oxygen when exposed to the

air, and must be kept in oil or other substances that do not contain oxygen. It does not occur in the free state, but is always combined with other elements, as carbonates, sulphates, silicates, and chlorides. Potash is an oxide of potassium, and feldspar and mica consist largely of this element. Potassium is present in the ash of all plants, is found most abundantly in the growing parts, and is essential to plant life.

Sodium (Na) is a soft, waxy, lustrous white metal much like potassium in appearance and always occurs combined with other elements. It oxidizes even in water and must be kept in fluids lacking oxygen. Its various combinations are abundant in the rocks. Sodium chloride ($NaCl$) is rock salt. What we commonly call soda is an oxide or carbonate of sodium. Chile saltpeter, or nitrate of soda, is largely used as a fertilizer. Sodium, while usually found in plants, is known to be non-essential, though it may take the place of potassium in neutralizing some of the acids formed in them. The chemical symbol is taken from *natrium*, the name by which it was formerly known.

Magnesium (Mg) is a light, silvery white, moderately hard metal which is malleable but not very tenacious. It is not found native, but forms many compounds. It is permanent in dry air, but tarnishes in the presence of moisture. Burned in oxygen, it produces a blinding light and forms magnesium oxide (MgO), or magnesia. Dolomite and asbestos contain much magnesium, and Epsom salts is the sulphate of this element. Magnesium is found in most parts of the plant, but less abundantly than calcium, except in the seeds, where it is usually more abundant.

Calcium (Ca) is a pale yellow, malleable, ductile, but somewhat brittle, metal. It is widely distributed, but never free. It is the chief element in marbles, limestones, and dolomites. Limestone is calcium carbonate ($CaCO_3$), and when carbon dioxide is driven off by burning, quicklime (CaO), which is used in plastering, is left. Gypsum is calcium sulphate ($CaSO_4$).

Plaster of Paris is derived from gypsum by burning. The rock called apatite contains large amounts of calcium phosphate. Calcium is one of the elements essential to plant life. It is posed to neutralize the acids that would otherwise injure the plant, as well as to play an important part in the production of new tissues. Some plants, such as clover, beans, and peas, are often called *lime plants* because they require so much of this element for their proper development.

Aluminum (Al) is another of the white metals that is never found native, though it is the principal constituent of every clay bank and forms one twelfth of the earth's crust. It is malleable and ductile and does not oxidize in the air. Clays and feldspars are silicates of aluminum, and the ruby, emerald, oriental amethyst, and sapphire are crystalline forms of the same metal combined with oxygen. Corundum, or emery, is an impure crystalline form. Though the metal itself is soft, the crystalline forms are exceeded in hardness by the diamond only. Alum is a combination of sulphur and potassium with aluminum. Aluminum is usually found in plants, though it forms no part of the plant food.

Iron (Fe) is too well known to need description. It is abundant and widely distributed, occurring usually as carbonates and oxides. It is an ingredient in practically all soils and forms about one fifteenth of the earth's crust. Iron rust and the ochers are oxides of iron, and it is these substances which give the red and yellow colors to certain soils. Iron is essential to plants. Its presence is necessary for the formation of chlorophyll, the green color of plants, though, so far as known, it does not enter into the composition of the color.

Manganese (Mn) is a hard, grayish-white metal that is fused with difficulty, but readily oxidizes. While often found in plants, it has been proved that it is not necessary to their growth.

Oxygen (O) at ordinary temperatures is a colorless, odorless gas. It is the most abundant of the elements, forming as it does one fifth of the air, eight ninths of the water, and about one half of the rocks and soil. It combines with a great number of other elements, forming oxides, and is necessary for all ordinary combustion and for the respiration of animals and plants. With hydrogen and carbon it forms the carbohydrates, of which the greater part of the plant body consists. Iron and other metals burn in pure oxygen.

Hydrogen (H) is a colorless, tasteless, and odorless gas, and is the lightest substance known. It does not occur free, but is most abundant combined with oxygen in the form of water. It burns with a blue flame and is a constituent of all acids. Hydrogen and oxygen, if mixed at ordinary temperatures, will remain a mere mixture, but if heated or ignited they combine with a violent explosion and form water.

Nitrogen (N) is a heavy, inert, colorless, tasteless, odorless gas that occurs free in the air, of which it forms about four fifths. It is extremely inert, does not support combustion, nor readily enter into combination with other elements. It is fourteen times as heavy as hydrogen, and without it the air would have little weight, birds could not fly, and the sails of ships and windmills would be practically useless. Nitrogen also serves to dilute the oxygen in the air; otherwise oxidation in our bodies would proceed so rapidly as to be harmful. Ammonia gas is largely nitrogen, and gunpowder, guncotton, and nitroglycerin owe their effectiveness to the fact that these are unstable compounds containing this element. Nitrogen does not exist in the mineral matter of the earth, though the soil is the source of most of this element used by plants. Here it exists largely in the form of nitrates derived from the decaying organic matter. Nitrogen is necessary to the formation of proteins and is an essential constituent of the protoplasm of all animals and plants.

Chlorine (Cl) is a heavy, yellow-green, poisonous gas, with a disagreeable, suffocating odor. It is never found free, but is widely distributed in nature in compounds, the most familiar of which is common salt ($NaCl$). Chlorine apparently takes no part in the life processes of plants, but is common in the compounds used by them.

Carbon (C) is a black solid, familiar to us in charcoal and mineral coal. Graphite, or black lead, used in pencils, is another form of this element. The diamond, the hardest substance known, is a crystalline form of carbon. Peat and muck are impure forms. Carbon has never been liquefied, but it may be turned to a gas at very high temperatures; many of its compounds are gases or liquids at ordinary temperatures. When carbon unites with oxygen, heat and light result. In slow combustion, such as that in our bodies, no light is produced, but the amount of heat that finally results is the same as if the substances burned more rapidly. The carbon so abundant in plants is not derived from the soil, but from the small quantity of carbon dioxide in the air. Carbon is believed to occur in more different compounds than any other element.

Phosphorus (P) is a pale yellow, poisonous substance about as soft as wax and has a disagreeable odor. It does not occur native, but in such combinations as phosphates of lime and aluminum it is present in large quantities in many rocks. It burns with a yellow-white light when exposed to the air, and must be kept under water in the laboratory. Phosphorus is a necessary constituent of the nucleus of plant and animal cells and is also found in considerable abundance in seeds.

Sulphur (S) is a yellow substance occurring native or combined with various elements, as sulphates and sulphides. It melts readily, and burns with a bluish flame and suffocating odor, producing sulphur dioxide (SO_2). Sulphur is an essential element in all plant and animal bodies.

Silicon (Si) when pure consists of lustrous brown or black crystals, but it does not exist in nature uncombined. Next to oxygen it is the most widely distributed of the elements and forms one fourth of the earth's crust. In combination with oxygen, silicon forms the clear and glasslike mineral quartz (SiO_2), and is thus the principal element in sand. From 60 to 90 per cent of most soils is quartz.

PRACTICAL EXERCISES

1. Look over the list of chemical elements given on page 3 and name those possessed by the class in the shape of jewelry, coins, etc.

2. Make a list of these and of the others that may be found in the schoolroom.

3. Visit the chemistry department of the school, or the nearest drug store, and list any other uncombined elements that you may find.

4. In the laboratory, by appropriate experiments, make carbon dioxide, sulphur dioxide, magnesium oxide, etc.

5. Pick out the chemical elements in the following combinations: orthoclase ($KAlSi_3O_8$), carnallite ($KClMgCl_2 6 H_2O$), common salt ($NaCl$), Epsom salts ($MgSO_4$), copperas ($FeSO_4$), nitric acid (HNO_3).

6. Burn a piece of limestone to drive off the CO_2, leaving quicklime (CaO). Add water to a piece of quicklime to make calcium hydroxide and note the heat developed by the chemical reaction.

7. Boil some water in a Florence flask and watch the space above the boiling water. What is the color of the gas (steam)?

8. Watch the bubbles of gas rising from any water plant when in sunlight. Catch some of it by sinking a short-stemmed glass funnel into the water over the plants, with the stem just below the surface, and inverting over it a test tube filled with water. The gas will rise and displace the water in the tube and may be tested with a glowing splinter.

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Hopkins, "Soil Fertility and Permanent Agriculture."
Snyder, "Chemistry of Plant and Animal Life."

CHAPTER II

ORIGIN OF THE SOIL

What the soil is. All ordinary plants are rooted in the soil, which serves them as a source of food materials and affords a convenient place of anchorage. The soil, however, is far from being the simple collection of rock fragments that it is often supposed to be. Fragments of rock are important, to be sure, and in ordinary soils form from 60 to 95 per cent of their weight; but any good agricultural soil must contain, in addition, air, water, humus, bacteria, and similar organisms. So important are all of these that none can be omitted without impairing the fertility of the land. From the rock fragments come all the minerals used by plants. These are steadily, though very slowly, dissolved out by the soil water and carried in solution into the plant. The humus, formed of decaying plant and animal remains, is the principal source of the all-important nitrogen; but since the plants cannot use it as humus, it must first be worked over into nitrates by the bacteria. The higher plants are so dependent upon the good offices of the bacteria in this respect that if the latter should all disappear from the soil, crops would soon be unable to grow in it. The air in the soil is required for the activities of the bacteria, as well as for the respiration of the underground parts of the plants.

Depth of the soil. The soil ranges from a few inches to many feet in depth. In *humid* regions — that is, in regions of abundant rainfall — the decaying humus gives it a darker color and enables us to distinguish it from the underlying materials; but in *arid* regions, where the rainfall is scanty, the humus is

destroyed almost as fast as made, and no such difference in color may be seen except in the occasional low, wet lands. The soil in arid lands, however, is often more fertile than that of humid regions and can be cultivated to a greater depth. This is mainly because the scanty rainfall has not washed out and carried away the food materials in it. Such soils need only to be irrigated to give abundant crops.

The subsoil. The soil is commonly regarded as extending downward as far as traces of organic matter or humus are found. In humid regions this is from a few inches to several feet. Below this is the subsoil, lighter in color, more compact, and consisting almost entirely of rock fragments. It is therefore little adapted to growing crops, though rich in the materials needed by plants. While not of itself able to produce good crops, it forms a storehouse of food materials upon which the plant can draw, and, slowly breaking down under the attacks of wind and weather, gradually becomes part of the soil itself.

Origin of the soil and subsoil. If one digs down far enough anywhere on the earth, he comes at last to the solid rock. This is called *bed rock.* Here and there it comes to the surface, forming *outcrops*, such as may be seen in the cliffs of broken country or where a rapid stream has carved out a deep valley. Usually, however, it is buried under a thick deposit of rock fragments, called *mantle rock*, which has been derived from the bed rock in various ways. Sections of mantle rock may be seen in railway cuts, gravel pits, brickyards, and the openings for quarries and mines. Since the bed rocks range from soft and porous sandstones and limestones to compact and flinty granites, the mantle rock may differ in composition according to the locality, and the soil derived from the mantle rock necessarily partakes of the same characteristics. Soils derived directly from the underlying bed rock are known as *residual* or *sedentary* soils; those brought

from a distance by running water or other means are called *drift* or *transported* soils.

Weathering. The agencies that have served to break up the bed rock into mantle rock and the mantle rock into soil are grouped under the general title of *weathering* agencies. Two phases of weathering may be distinguished, namely, weathering by *decomposition* and weathering by *disintegration*. The first is largely a chemical process in which some or all of

FIG. 1. An outcrop of limestone showing weathering

the minerals in the rock are resolved into their simpler compounds, resulting in very fine particles; the second is largely a mechanical or grinding process and the resulting particles are usually larger.

Weathering by decomposition. Air and water are the chief elements that are effective in decomposition. The oxygen in the air readily enters into combination with other elements in the rocks and soon tears down the surface layers exposed to it, forming new compounds. Results of this process are seen in the rusting of iron and the dulling of nearly all surfaces exposed to the air for any length of time. In the quarry we

readily distinguish the newly quarried blocks from older ones by their fresh look. The carbon dioxide in the air unites with water to form carbonic acid, and this also attacks various elements in the rocks and tears them from their compounds.

Water breaks up the rocks by dissolving out the more soluble compounds. Pure water wears the rock very slowly, but when it contains, as it often does, carbon dioxide or other acids derived from the humus or the roots of plants,

FIG. 2. Underground channel in limestone made by water, Joliet, Illinois
A portion of the rock has been dissolved and carried away

it is a most powerful agent in weathering. Limestones, especially, are quickly dissolved by such means, and the occurrence of caves and underground channels in these rocks is thus explained. Here and there water charged with dissolved minerals may come to the surface and we then have mineral springs. Sandstones, though usually more enduring than limestones, are often rapidly disintegrated by having the materials which bind the sand grains together dissolved. Rain water usually contains small amounts of ammonia and nitric acid, and these, like the carbonic acid, are active in dissolving

the rocks. The weathering effects of water are not confined to a layer near the surface, as in decomposition by the air, but extend downward as far as the water can penetrate.

Photograph by H. L. Hollister Land Co.

Fig. 3. A deep valley in Colorado, excavated mainly by running water

Not only does the water dissolve the rocks, but it carries the dissolved materials away to be deposited elsewhere when the water evaporates, thus building up in one place what it tears down in another. In this way the stalactites and stalagmites found in limestone caves are formed, and our beds of rock salt, gypsum, and bog irons are due to the same process.

A cubic mile of ordinary river water has been estimated to contain about a quarter of a million tons of rock constituents. It is not difficult to understand, then, that in many soils formed by the decomposition of limestone rock, a layer of limestone nearly a hundred feet thick may have been removed for every

Photograph by H. L. Hollister Land Co.

Fig. 4. Twin Falls, Idaho

Here the Snake River has worn a channel hundreds of feet deep in hard igneous rock

foot of soil left. In contrast to this, water, under certain conditions, instead of decreasing the bulk of the soil in weathering, may actually increase it by entering in combination with some of the elements in the rocks. Thus granitic rocks in turning to arable soil may be increased in bulk more than 80 per cent.

Weathering by disintegration. By disintegration the rocks are broken up into small pieces like the original rock and suffer little, if any, chemical change. In this process heat,

cold, and gravity, and water influenced by these forces, are the important agents. Variations in temperature have a greater effect in weathering than is commonly supposed. Under the rays of the noonday sun, exposed rocks rapidly rise in temperature and expand; at night they as rapidly cool and contract. This alternate heating and cooling is

Photograph by H. L. Hollister Land Co.

FIG. 5. A crest in the Rocky Mountains showing rock fragments split off by alternating heat and cold

frequently sufficient to cause the splitting off of large flakes weighing many pounds, with reports like pistol shots. The different minerals in the rocks have their own rate of expansion and contraction, and if these varying movements under changes of temperature do not cause the actual splitting off of particles of rock, they leave minute openings between them into which water may penetrate and begin its work of dissolution. Changes of temperature have little effect upon

rocks that are not exposed, but the great banks of irregular fragments at the base of cliffs show how rapidly the work of tearing down the solid rock goes on under favorable conditions. When water is present in the rocks the lowering of the temperature below the freezing point causes weathering to progress still more rapidly, since the expansive force of water in freezing is equal to the weight of a column of ice a mile

Photograph by E. Vickers

Fig. 6. A hard portion of a rocky ledge

The softer parts have been carried away by the stream

high, or about 150 tons to the square foot. Most rocks go to pieces rapidly under alternate freezing and thawing. Even polished granite soon deteriorates in severe climates through the freezing of water that finds its way between the crystals in the rock. The obelisk known as Cleopatra's Needle, which resisted the atmosphere of Egypt for many centuries, began to deteriorate at once when removed to the latitude of New York, and had to be protected. When pieces of the rock have been chipped off by the cold and carried to the base of a cliff by gravity, running water may carry them for

long distances, dragging them over the bed rock, grinding them against other pieces, and rapidly reducing them in size, the finer particles being carried away by the current and deposited elsewhere. Waterworn pebbles are easily recognized by their rounded surfaces, and the fine sand and clay

Photograph by H. L. Hollister Land Co.

FIG. 7. A mountainous region showing the weathered crests and snow-filled valleys

to be found in every shallow are but deposits of rock dust ground from the pebbles by the streams.

It is not alone the particles of rock in the stream beds that are carried away by running water. During every heavy rain the torrents of muddy water running away from cultivated fields show how rapidly the most fertile parts are being removed. When the current slackens, this material is dropped, the largest particles first, the smallest much later. The latter often continue suspended in the water for days.

The delta at the mouth of many large rivers is made up of these finer particles, and consequently delta soils are among the most fertile in the world.

Work of glaciers. Another most effective agent in grinding up the bed rock, but one that is no longer active in our country, was the great ice sheet that ages ago spread from colder regions southward over a large part of North America. One or perhaps several of these extended their movements to central Pennsylvania and the Ohio River valley, and westward nearly to the Rocky Mountains. In the northern part of the United States the ice sheet was a mile or more thick and moved over the country with irresistible force, breaking off great fragments of rock as it went, and now advancing with a cold season, now retreating with a warm one, ground the immense rocks to bowlders, the bowlders to pebbles, the pebbles to sand, and the sand to powder. The interior of Greenland is still covered with such an ice sheet, and similar accumulations of ice in the form of glaciers are found in Switzerland, the Rocky Mountains, and other elevated parts of the world, where the process of grinding up the bed rock in this way may still be witnessed. Upon the final retreat of the ice sheet the country over which it moved was left strewn with vast deposits of rock fragments, and these, sometimes intermingled, sometimes sorted out by running water into beds of clay, sand, and gravel and thrown up into hills and ridges, between which were many small lakes and marshes, cover much of the country in the northeastern states. The topography of a glaciated country is quickly recognized by the geological student.

Modifications of the bed rock. It is believed that not only has the mantle rock been derived from the bed rock by processes already noted, but that much of the bed rock itself was originally formed from harder rock that was first weathered into small particles and later consolidated by various

forces. The rocks from which all the other rocks are supposed to have been derived are called *igneous* rocks. They are hard and compact, and include the granites, diorites, basalts, and lavas. Usually they are found deep in the earth and are buried under not only many feet of mantle rock but of other bed rocks as well. Rocks derived from the igneous

Photograph by H. L. Hollister Land Co.

FIG. 8. Glacier-covered slope in the Rocky Mountains

Note the banks of rock fragments which have been carried down by the ice

rocks are called *sedimentary*, or *aqueous*, rocks because they are regarded as having first been laid down in the bottom of shallow lakes or seas as beds of mud, sand, or gravel, and later compacted into rock. Limestones, sandstones, and shales are some of the better-known sedimentary rocks. Some of the sedimentary rocks have been subjected to great heat and pressure since their formation, thus altering their structure. Such rocks are called *metamorphic* rocks. Slates, marbles,

and quartzites are good illustrations of metamorphic rocks. By consulting the following table the student should have no difficulty in discovering to which group the rocks in his own region belong.

TABLE OF ROCKS

I. Igneous.

1. Granite.
2. Basalt.
3. Diorite.
4. Lava.

II. Sedimentary, or Aqueous.

A. Inorganic.

1. Argillaceous — shale (formed from clay).
2. Silicious.
   a. Sandstone (formed from sand).
   b. Conglomerate (formed from pebbles).
   c. Breccias (formed from irregular fragments).
3. Chemical — bog iron, rock salt, gypsum.

B. Organic.

1. Calcareous — limestone (formed from animal remains).
2. Carbonaceous — soft coals (formed from plants).
3. Silicious — diatom earth, chert.

III. Metamorphic.

1. Slate (derived from shale).
2. Quartzite (derived from sandstone).
3. Marble (derived from limestone).
4. Anthracite (derived from soft coals).

Changes in mantle rock. The weathered fragments of the bed rock have not lain undisturbed where they fell. The work of weathering is unceasing. Little by little the particles have been reduced in size; running water has sorted them over time and again; floods from the melting ice sheet have spread them out; ants, earthworms, and other animals have slowly turned them over, bringing deeper layers to the

surface; generation after generation of plants have grown in the débris, and, dying, have left their remains to enrich the deposit; bacteria, the smallest of living things, have here found a congenial home and have added their share to

Fig. 9. A glaciated valley in southern New York

Note the irregular surface

the cycle of changes; thus have the ragged fragments of rock that in the beginning were unable to support the growth of plants been turned into the rich and fertile soil in which are grown the luxuriant crops upon which the very life of man depends.

PRACTICAL EXERCISES

1. In the school garden measure the depth of the soil by making an opening down to the subsoil. Compare this as to depth with any other soil sections with which you are familiar.

2. Ascertain from wells, railway cuts, trenches for sewers, and the like the average depth of the mantle rock in your vicinity.

3. If the mantle rock varies in depth in your locality, make a table to show this.

4. Make a collection of specimens to illustrate the kinds of rock in the table on page 22.

5. Make a list of the different kinds of bed rock in your vicinity.

6. Visit a gravel pit and collect as many different kinds of rock fragments as possible.

7. Make a list of all the above-mentioned fragments that are unlike the bed rock in your region.

8. Visit the best farm or garden in the vicinity and decide whether the soil is a sedentary or a transported one.

9. Visit the nearest outcrop of rock and search for signs of weathering. Make a list of all forms seen. Decide which is more effective in that place.

10. Make a similar visit to a field on a hillside.

11. Account for differences in the color of the soil on hilltops and in lowlands. In which are the crops best? Why?

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CHAPTER III

TYPES OF SOILS

Named for their origin. Soils, as we have seen, may be divided into residual and drift soils, depending upon whether they have originated from the underlying rocks or have been transported from distant regions by water and other agencies.

FIG. 10. Vegetation invading a shallow lake

It is possible, also, to name the soils from the agencies most active in forming them, and the principal groups thus naturally break up into smaller divisions. The residual soils may be divided into the true sedimentary and the lacustrine, while drift soils include the æolian, volcanic, colluvial, glacial, and alluvial.

Photograph from American Steel and Wire Co.

FIG. 11. A small pond nearly filled with aquatic vegetation

Sedentary soils. Sedentary soils are formed from the underlying rock, either by decomposition, disintegration, or by a combination of both. In limestone regions the soluble part of the rock may be carried away by the water, leaving a soil

quite unlike one made from limestone fragments. Such soils may actually need to have lime added to them to enable them to produce good crops. Sandstone rocks are formed of grains of sand cemented together by lime, clay, iron, or silica. When the cementing material is dissolved out by water, a sandy soil is left. Other residual soils may be formed from weathered fragments of the original rock from which little has been carried away by water, as in many soils derived from granite rocks.

Photograph by A. B. Klugh

FIG. 12. A moving sand dune

Lacustrine soils. These differ from true residual soils in having been built up in lakes and ponds by an accumulation of plant and animal remains, together with fine particles of rock brought in by rains or blown in by wind. In our Northern states many of what were once shallow lakes have been completely filled in this way and now contain a rich black soil much valued for growing certain crops, such as celery. Such soils, however, often lack some of the minerals needed by plants, and these have to be supplied before good crops can be produced.

Æolian soils. These have been transported by wind. Sand dunes are familiar examples. Less well known, though more important, are the deposits of wind-blown materials known as *loess* that cover large areas in China, Europe, and parts of the Middle West. Loess is composed of particles much finer than sand grains and makes very fertile soils. Parts of Iowa and Kansas are covered with loess to the depth of hundreds of feet.

Photograph by A. B. Klugh

FIG. 13. A sand dune captured by vegetation

Volcanic soils. As the name indicates, these are formed of the ashes and dust thrown out by volcanoes. They are rare in the United States except in the Far West, but in other countries are often encountered. After weathering, they form very fertile soils. Much of the land cultivated in the Hawaiian Islands is of this type.

Colluvial soils. These have been formed by gravity acting upon the pieces of rock quarried from the cliffs by changes of temperature and freezing water. Good illustrations are found

in the banks of talus at the base of cliffs almost anywhere. The soil brought down by avalanches also belongs to this class. Since the materials that compose it are coarse, rough, and irregular, a colluvial soil is of little value for cultivation, though it may support a luxuriant growth of lichens, mosses, ferns, and small shrubs. The soil on hillsides may also be regarded as partly colluvial.

Glacial soils. Glacial soils have been derived from many kinds of bed rock by the glacial ice that once covered a great part of the northeastern states and various other parts of the earth. They consist of sand, clay, and gravels either separate or intermingled. Such soils are the rule in the states north of the Ohio River and east of the Great Plains, but south and west they gradually thin out and disappear.

FIG. 14. A ridge of glacial débris that has been sorted by running water

Alluvial soils. These have been transported by streams that during periods of flood pick up much material that is dropped as soon as the current slackens. The soil in our ordinary bottom lands has been formed in this way, and the soil in the delta region along the lower Mississippi is of the same nature. Alluvial soils are extremely fertile, since they consist in great measure of the richest soil washed down from other fields.

Soil constituents. Ordinary arable land is a mixture of various ingredients. When these are separated, we know them as sand, clay, silt, humus, and the like. *Peat* is a black

deposit formed by the decay of plants under water, and may be seen in the process of formation along the shores of many lakes and ponds. It also occurs in extensive deposits called peat bogs, which mark the site of old lakes that have been filled by such accumulations. When pure, peat contains enough carbon to make it useful as fuel. Most of our coal beds have been formed from peat. *Humus*, sometimes called vegetable mold or leaf mold, is, like peat, formed from plant remains, but in this case the decay has taken place in or on the soil. It is a black, loose substance usually abundant on the forest floor and is an indispensable element in all fertile soils. *Muck* is a black deposit, midway between humus and peat, that occurs in swamps and low grounds. The words "peat" and "muck" are often used rather loosely to designate the same substance. *Marl* is a deposit of lime and clay, like a whitish mud, which forms at the bottom of ponds. The lime is derived from the decay of the shells and bones of water animals. Marl is valued for adding to soils deficient in lime. *Clay* is a soft powder or rock flour usually resulting from the weathering of feldspar rocks. Clay consists of particles less than one five thousandth of a millimeter in diameter,

FIG. 15. Section of an abandoned quarry partly filled with water

The dark deposit at the top of the exposure is peat, the light material below is marl, beneath this is the mantle rock which merges into the bed rock

and a cubic foot of it weighs from seventy-five to eighty pounds. Clay is powdery when dry, sticky when wet, and is easily molded. *Silt* consists of particles somewhat coarser than clay. They range in diameter from five thousandths to five hundredths of a millimeter. When moist, silt becomes a soft mud, and in drying inclines to crumble. *Sand* consists of loose hard grains from five hundredths of a millimeter to one millimeter in diameter, resulting from the weathering of sandstones and quartzes. The grains may be angular or rounded, but are always harsh and granular to the touch. A cubic foot of sand weighs from one hundred to one hundred ten pounds. Wet sand is held together by the moisture; when dry, the grains at once fall apart. *Gravel* is a mixture of many kinds of rock fragments and differs from sand chiefly in the size of the particles composing it. The smaller fragments are called *pebbles;* the larger, *bowlders.* Glacial pebbles are angular in shape. When pebbles are rounded it is an indication that they have been worked over by water. Gravel is usually accompanied by varying amounts of sand and clay, and often forms rich soils. Peat, muck, marl, and humus are all of *organic* origin; clay, silt, sand, and gravel are *inorganic.* The nature of the soil greatly influences the plants that grow on it. This is shown from the fact that plants on the same kind of soil in different parts of the world resemble one another.

Sand and clay contrasted. The best soil for ordinary crops is a mixture of clay, sand, silt, and humus. Owing to the contrasting characters of clay and sand, the soil is heavy or light, cold or warm, moist or dry, worked with difficulty or easily worked, according to whether one or the other predominates. Neither forms a good soil by itself, but intermingled in various proportions they give a wide range of soils from which the farmer and gardener can select one suited to the crop he proposes to grow. Clay consists of the finest of soil particles. It would require 400,000 of the smallest, side by

Photograph by United States Forest Service

Fig. 16. A badly gullied hillside, the work of running water

side, to measure an inch. Clay is slow to absorb water, and its reluctance in this respect causes it to gully badly in heavy storms. It is equally slow to give up moisture once absorbed. The particles of wet clay cling together with great tenacity, and as they dry they form a compact mass traversed by numerous cracks, due to the shrinking of the mass as the water evaporates. The total surface of the particles of clay to which the water clings is very great. When thoroughly wet it is able to hold much water, often as much as 40 per cent. In wet weather, therefore, it may contain too much water for good crops, while in dry weather it may bake and become too hard for the roots of plants to penetrate. Owing to its great water content, it warms slowly, but it cools as slowly, and in autumn the vegetation lasts longest on the clays. Because of the smallness of the particles composing clay, the air spaces are correspondingly small. In consequence the air cannot move through it freely and it is always poorly aërated in spite of the fact that it contains a greater amount of pore space than sand. Clay is the source of considerable plant food, mostly potash, and it also fixes other plant foods that may be in the soil. The farmer calls clay a cold and heavy soil, but the heaviness refers to the difficulty with which it is worked, and not to its weight, for it is much lighter than sand.

Sand consists of hard separate grains. These have little tendency to stick together, even when wet, though in certain positions, as on seabeaches, they may form a firm, hard surface when saturated with water. Sand does not bake nor crack, and in drying returns to the loosely granular form. It absorbs water readily and as readily gives it up. It often contains less than 5 per cent of water. Plants, however, can get more of the contained moisture from sand than from clay. Sand does not gully as badly as clay because it so rapidly absorbs water. It warms up quickly and cools much more rapidly than clay. Owing to its large air spaces, air moves

through it readily. Sand contains very little plant food because this is so easily washed out by the rains. It is called a light soil because it is so easily worked, though, bulk for bulk, it is heavier than any other. The roots of plants penetrate sand without difficulty, but the readiness with which it parts with its moisture renders it unsuitable for most crops. Like clay, sand is of a variety of colors. Reds and yellows, due to compounds of iron, are most abundant.

Loam. A soil containing about equal parts of sand and clay with some humus is called loam. If the sand is in excess, it is called a sandy loam; if the clay predominates, it is a clay loam. Other constituents in the soil may modify it sufficiently to entitle it to some other designation, as silt loam or gravelly loam. Clay soils have from 80 to 100 per cent of clay; clay loams, from 60 to 80 per cent. Sandy soils have from 80 to 100 per cent of sand; sandy loams, from 60 to 80 per cent. The national Department of Agriculture is at present analyzing and mapping the soils of the United States. As fast as mapped, each type of soil is given a name to distinguish it. This is usually derived from some town located upon the soil indicated, as Hammond silt loam, Hagerstown loam, and Miami sand.

Alkali soils. In various parts of the West the soils contain an excess of the salts of sodium, magnesium, calcium, and potassium, in which the ordinary cultivated plants will not grow. Such soils are known as *alkali soils.* They usually occur in regions deficient in rainfall, and the deposits are due to the fact that the water from the scanty rains soon evaporates, leaving on the surface the salts it has dissolved out of the soil. Among these salts may be such familiar substances as common table salt, Glauber and Epsom salts, and sal soda. Many wild plants are not very sensitive to these salts and may even thrive in such soils, but before the crops of the farmer will grow, the alkali must be removed. In many soils this is

accomplished by flooding with water. In using this means care must be taken to see that proper underdrainage is provided by means of tiles, if the natural drainage is not sufficient.

Acid soils. Some soils will not support a good growth of cultivated crops because of various acids left in them by the decaying vegetation, which hinder the growth of the bacteria necessary to turn the humus into available plant food. Such soils are called *acid*, or *sour*, soils. Though not adapted to ordinary crops, sour soils may support a luxuriant vegetation, and some wild plants have become so accustomed to acid soils that they will thrive in no other. Among plants of this kind may be mentioned huckleberries, cranberries, trailing arbutus, and many other plants of the heath family. Most of the plants found in peat bogs are lovers of acid soils. On the other hand, clover, beans, peas, and other legumes are very intolerant of such soils and cannot live in them. Lettuce, beets, spinach, and timothy are other plants that will not grow in sour soils. The majority of sour soils are found in low and poorly drained districts, but the proper combination of conditions will turn any soil acid, and many upland soils are of this kind. The bird's-foot violet, sorrel, and beard grass (*Andropogon*) are regarded as indicators of acid soils in uplands. When mosses grow on the lawn or in the fields it is also a pretty sure indication of a sour soil.

FIG. 17. A pitcher plant (*Sarracenia*), a characteristic plant of acid soils

A test for acid soils. To discover whether a given soil is acid or not, make it into a thin mortar with water and test with blue litmus paper, or inclose a piece of the paper in a ball

of the moist soil for a few minutes. If the paper turns red, the soil is acid. Litmus paper may be found in any chemical laboratory or at the nearest drug store. Blue litmus paper has the property of turning red in the presence of acids, and red litmus paper will turn blue in alkaline mediums. Acid soils are easily neutralized by the application of lime, marl, or gypsum.

Artificial soils. The florist and gardener often find it expedient to make artificial soils for their plants. Seedings and cuttings need a light and porous soil consisting largely of sand; ferns need a considerable proportion of humus. The grower, therefore, usually obtains peat, sand, leaf mold, and other ingredients and mixes his soil to suit the needs of the plants. A good potting soil for all ordinary plants is made by building up a mound consisting of a layer of sods from any good soil, a layer of sand, and a layer of stable manure; then another layer of sods, sand, and manure, and so on. This is allowed to stand until the sods have decayed, after which it is thoroughly mixed and is ready for use.

PRACTICAL EXERCISES

1. On a soil map of your region locate such types of sedimentary and drift soils as occur.

2. What is the name of the soil upon which the school garden is located? your own home?

3. Visit deposits of sand, clay, peat, marl, and humus and collect good samples of each for study.

4. Weigh a cubic foot of soil from the school garden and estimate the number of tons in an acre 7 in. deep.

5. Test the soil in the school garden and in your own garden for acidity. Make the same test of the soil in the nearest peat bog.

6. Make a list of the more conspicuous plants in a peat bog. Compare with a similar list from a meadow or pasture.

7. Pour ammonia water through a tube filled with powdered clay and examine that which filters through. What has become of the ammonia?

8. Measure out equal amounts of sand and clay and place in separate vessels. Add measured quantities of water to each until they are saturated. Which absorbs water more rapidly? Which absorbs the

greater amount? What per cent of water did each absorb? What filled the space before the water entered?

9. Fill a two-quart jar about two thirds full of soil from the school garden. Add water until the jar is full and let stand for a day. Then shake thoroughly and let the mixture settle. How do the various materials arrange themselves in settling? Determine from the experiment the kind of loam your soil is most like. Try the same experiment with the subsoil. Is the result the same?

10. Put about a pint each of soil and subsoil from the school garden into air-tight receptacles and bring into the laboratory. Test for moisture and organic content as follows: Procure two small pans and weigh them. Place 100 g. of soil in one and a like amount of subsoil in the other, weighing quickly to avoid loss by evaporation. Expose the soil to the air of the room for three days and weigh pan and soil again. The difference between this and the former weight will give the amount of capillary water each specimen contained. Now get two crucibles and place 10 or 15 g. of the dry soil and subsoil in them. Heat in an oven for five hours and weigh again. The difference in weight gives the amount of the hygroscopic moisture present. Next heat each sample to red heat over a Bunsen burner for half an hour and weigh again. The difference now represents roughly the amount of organic material in the soil. Fill out the following table:

	Soil	Subsoil
Weight of soil pan		
Weight of pan and moist soil		
Weight of pan and air-dry soil		
Amount of capillary moisture		
Weight of crucible		
Weight of crucible and soil after baking . . .		
Amount of hygroscopic water found		
Weight of crucible after burning		
Amount of organic matter present		

11. Breathe upon a glass slide, throw some sand upon it, shake off all loose grains, and examine those that remain with the microscope. The pink or black particles are hornblende; the thin, clear, or dusky flakes are mica; and the gray particles are feldspar or granite. Mix up some clay in water and examine a drop of the turbid fluid in the same way. How do the two mounts compare as to size and composition of the particles?

CHAPTER IV

CONDITIONS AFFECTING SOIL FERTILITY

Structure. While humus, water, and air are necessary constituents, mineral matter is the basis of all fertile soils, forming from 60 to 90 per cent of their weight. The prevailing mineral constituent is nearly always silica, with varying amounts of alumina or clay and the oxides of iron, calcium, magnesium, and others. Even in the poorest soils there are enough of the elements needed by plants for at least a hundred ordinary crops, and the subsoil contains immense additional supplies; but these are often so solidly bound in the rocks as to be only slowly available to plants. The texture of the soil, then, determines in great measure not only what crops can grow upon it, but the rapidity with which weathering can make the needed elements available. A block of stone will support only a few mosses and lichens; grind it to sand and many more highly specialized plants will grow upon it; reduce it to powder and it will grow our cultivated crops. A gram of good soil contains from two billions to twenty billions of soil particles. In a cubic foot of the finest clay the total exposed surface of the particles is not far from 175,000 square feet. In a sandy soil the area falls to about 10,000 square feet. The particles in a cubic foot of light loam have a total surface area of about one acre. Since water containing the dissolved food materials is held on the surface of these particles, one easily understands how a fine soil and a fertile soil are nearly synonymous terms. In the soil the finest particles are not separate, but are *flocculated*, or bound together in small groups called *soil crumbs*. When for any reason the soil crumbs are

broken down into their original particles, the soil is said to be *puddled*. The roots of plants, and the water and air necessary for their growth, have difficulty in penetrating puddled soils, and the farmer is careful not to work his land when doing so may induce this condition. Puddled clay is so impervious to water that it is often placed in the bottom of artificial ponds to prevent the water from leaking out.

FIG. 18. A stony field in southern New York, showing glacial débris

At the time the photograph was taken this field was planted with corn

The presence of lime and humus also has considerable effect on the texture of the soil. Lime has the faculty of flocculating clay soils, but in sandy soils small amounts of lime serve to bind the particles together; in addition, it serves to correct acid soils and promotes the growth of the soil bacteria. Humus makes heavy soils more open and promotes the movement of air in them, thus making them warmer. It also absorbs and holds for the plants nearly

twice its weight of water and is the source of most of the nitrogen used by them.

The air. We are living at the bottom of an ocean of air from which all the animals and plants derive elements necessary to existence. From it animals obtain the oxygen for respiration, while the plants, in addition to a similar use of oxygen, make use of the carbon dioxide, forming from it nearly half their dry weight. The air is made up of several gases, two of which, oxygen and nitrogen, comprise more than 98 per cent of its bulk. The proportions of the principal gases are given in the following table:

Nitrogen	77.95
Oxygen	20.61
Water vapor (average)	1.40
Argon	1.00
Carbon dioxide	0.03

The air also contains small quantities of krypton and neon. Water vapor, which varies in quantity with the locality, is not strictly a part of the air. The air is possibly several hundred miles deep and at sea level presses on every square inch of surface with a weight of nearly 15 pounds, or more than 46,000 tons, to the acre. The pressure varies somewhat with the weather, being greatest in calm, fine weather and least as a storm approaches. Differences in pressure are measured by the barometer, in which a column of mercury rises with high pressure and lowers with a decrease of pressure. These variations in pressure exert a considerable influence over the air and water in the soil. When the barometer is falling, the lessened pressure causes the air to flow out of caves, mines, and other underground cavities, while the water in wells rises and springs flow more copiously. In some localities the underlying porous rocks absorb so much air when the pressure is high that when it is relaxed the amount of air rising from wells and other openings in the soil may be sufficient to cause a

perceptible draft. Wells of this kind are called blowing wells and form very good natural barometers. When a storm approaches, the draft is outward, and when fair weather returns, the air flows back into the ground. The same phenomena aid in the ventilation of the soil, but even without this there is more or less exchange between the gases in the soil and those outside by a process of diffusion, in which different gases tend to mix until all parts of the mixture have equal amounts of each. The ventilation of the soil is also promoted by the air which flows in when the water, after a rain, sinks downward.

Air in the soil. About half the bulk of dry soil is pore space filled with air. Clay, although apparently more compact than sand, has a greater amount of pore space. The spaces, however, are smaller and the air moves more freely in sand. As has been previously stated, air is essential to a fertile soil. It supplies the underground parts of plants with the oxygen necessary for respiration, it makes the soil warmer, promotes the growth of soil bacteria, and aids in weathering. Ordinary plants cannot live in a saturated soil, and a few days' flooding may destroy an entire crop. Certain aquatic plants thrive in such soils, but these have become adapted to their habitat and have other ways of obtaining their oxygen.

Temperature. All parts of the earth receive the same amount of sunlight in the course of a year, but the shape of our planet makes the distribution of temperature very uneven. The heat is greatest where the sun's rays are vertical and least where they fall obliquely, since in the latter case the same amount of heat is distributed over a greater area. For this reason hillsides sloping toward the sun are warmer than level fields, while northern slopes are colder. Few realize the enormous heat received from the sun, although familiar with the fact that a lens may bring together the few rays that fall upon it and set fire to paper or wood. It is estimated that the energy received from the sun is equal to one horse power per hour for

every square yard of surface. A man of average size lying on the earth will receive more heat in one hour than is needed to raise a gallon of water to the boiling point. The same heat would raise the temperature of a layer of soil, half an inch thick, nearly 90 degrees.

Variations in temperature. The changes of the seasons and the alternations of day and night cause the temperature of middle latitudes to range from many degrees below zero to more than a hundred above in the course of a year. These changes affect the soil for some distance downward, though in most parts of the United States the difference between the day and night temperatures is not perceptible three feet below the surface, and at seventy-five feet below, summer's heat and winter's cold are alike unknown. This explains the fact that water from deep wells is cool even in summer. In the tropics this point of unvarying temperature, both for day and night and for the seasons, is little more than a foot below the surface. Much of the heat received by the soil is used in evaporating the water in it. For this reason wet soils are cold soils. The heat used in evaporating one pound of water would warm 7500 pounds of soil one degree. Some of the heat falling on the earth is also reflected back and serves to increase the temperature of the air.

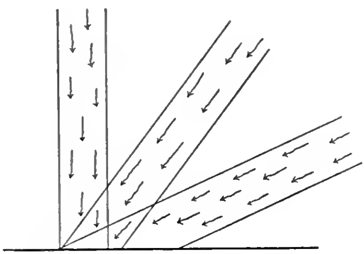

Fig. 19. Diagram to show the distribution of the sun's rays

When the sun is near the horizon, the same amount of heat is spread over a greater area than when it is overhead

Other factors that modify temperatures. The temperature of the soil is also affected by its color, slope, and composition. Southern slopes are warmer than northern slopes because they receive the more direct rays of the sun. Soils sheltered from

the sun in any way are cold; hence the saying, "There is a difference of 100 miles of latitude between the north and south sides of a tight board fence." The fence not only shuts off the heat rays from one side of it, but it reflects back much heat to the soil on the other. The best place for the early vegetables is on the sunny side of such a fence. We see other effects of the reflection of heat in our greenhouses and hotbeds, where the air under the glass is warmed in large measure by the heat reflected back from the soil. Dry soils are warmer than wet ones, and well-aërated soils are warmer than those in which the air does not circulate freely. Color also influences the amount of heat absorbed by soils. Black soils absorb most, red next, yellow next, and light soils least of all. In an experiment with two samples of the same soil, one of which was whitened with magnesia and the other blackened with lampblack, there was found to be a difference of more than 12 degrees in favor of the black specimen. A soil containing much humus is warmer than one that lacks it. The decay of organic matter adds as much warmth to the soil as would be given off if the matter were burned more rapidly in the air.

The Fahrenheit and centigrade scales. There are two scales in common use by which temperature is measured. In both, the freezing and boiling points of water are cardinal points. The Fahrenheit scale is the one most used in the United States at present. On this scale zero is placed 32 degrees below the freezing point of water, and the boiling point 180 degrees above it, making 212 degrees between zero and the boiling point. A much better arrangement is found in the centigrade scale, where the freezing point of water is called zero and the distance between it and the boiling point is divided into 100 degrees. A degree in the centigrade scale is therefore larger than a degree Fahrenheit. To change a given number of degrees centigrade to Fahrenheit one must multiply by $\frac{9}{5}$ and add 32 ($C. \times \frac{9}{5} + 32 = F.$). To change Fahrenheit to

centigrade, subtract 32 and multiply by $\frac{5}{9}$ ($F. - 32 \times \frac{5}{9} = C.$). Below zero centigrade one multiplies by $\frac{9}{5}$ and subtracts the product from 32, if it is not more than 32. If more, the difference between this and 32 indicates the degrees below zero Fahrenheit. If the temperatures below zero Fahrenheit are to be changed to centigrade, add 32 and multiply by $\frac{5}{9}$. The result will be degrees below zero centigrade. In all cases

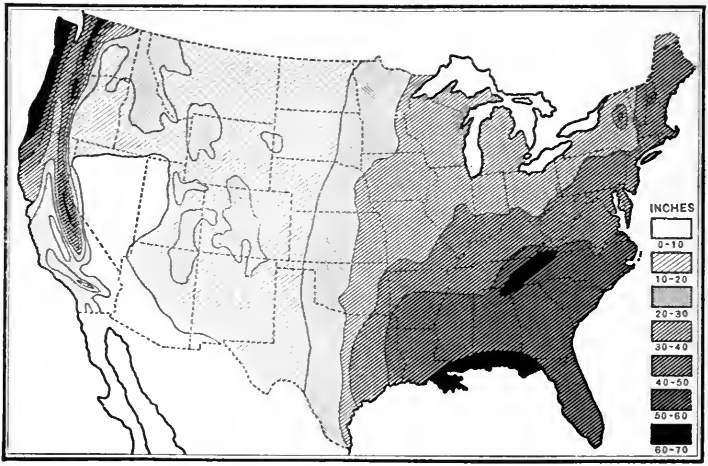

FIG. 20. Mean annual rainfall in the United States

From Brigham's "Commercial Geography"

where temperatures are recorded without the scale indicated, as in this book, it is understood to refer to the Fahrenheit scale. The centigrade scale, however, has found favor with scientific men, and it is probable that in the near future it will supplant the other.

Precipitation. The most important function of the soil is to afford water for plants. In many parts of the West thousands of acres are barren and useless for want of this indispensable factor. When it is applied to the soil in irrigation, the desert at once becomes a garden. Precipitation may occur as rain,

snow, hail, or dew, and varies with the locality and season, being usually greatest near coasts where moisture-laden winds blow inland, and least where the prevailing winds blow in the opposite direction. On parts of the Gulf coast the annual rainfall is about 70 inches, on the northwest coast it may be from 105 to 112 inches. In the Mojave desert, surrounded by mountains that intercept the moisture, it is less than 2 inches a year.

Precipitation at Joliet, Illinois, for Four Years

illustrating variations that may occur

Month	1908	1909	1910	1911
January	.77	1.12	2.52	1.58
February	2.66	3.38	2.45	1.62
March	4.33	1.56	.24	1.39
April	3.32	6.60	3.81	4.45
May	6.95	3.46	4.90	3.65
June	1.30	3.80	.81	4.65
July	3.79	1.69	1.46	2.46
August	3.80	2.95	3.17	4.54
September	1.32	3.09	2.75	12.27
October	.82	1.68	1.68	4.18
November	2.77	4.55	.62	2.87
December	1.30	3.50	1.12	1.91
[1] Annual	33.13	37.38	25.53	45.57

The heaviest rainfall in the world is found in the Khasi hills, north of the Bay of Bengal, where the precipitation may reach 600 inches a year. More than 40 inches have fallen in a single day there. The rainfall of the United States seems generally to increase as one goes eastward. Over much of the Rocky Mountain region it is from 10 to 20 inches, on the western edge of the Great Plains it is from 20 to 30 inches, in the north-central states it is from 30 to 40 inches, and the eastern states

[1] The average annual precipitation at this station for eighteen years is 34.58 inches.

have from 40 to 50 inches. Over most of the Gulf states the rainfall is from 50 to 60 inches. About 215,000,000,000,000 cubic feet of water fall annually in the United States. This would cover 5,000,000,000 acres a foot deep, or keep ten Mississippi rivers constantly flowing. In figuring precipitation, 10 inches of snow are considered equal to 1 inch of rain. Dew may form within the soil as well as upon it, but the amount of moisture added in this way is negligible. Dry soils

Photograph by H. L. Hollister Land Co.

Fig. 21. Sagebrush on the Western plains

The rainfall is insufficient for cultivated crops, but when irrigated the land yields abundant harvests

are also able to absorb moisture from damp air, the moisture condensing upon the soil particles. Sands absorb least and humus most. Quicklime slakes when exposed to the air, by absorbing moisture in this way. So strong is this tendency of quicklime to absorb moisture that the chemist uses it to dry the air used in various experiments. A fine soil will also absorb moisture from a coarser one. Clay may sometimes take water from sand, though the latter may contain less moisture than the clay.

Water in the soil. A part of the water which falls in rain immediately evaporates, a part sinks into the soil, and the rest drains away into streams and ponds. This latter is known as the *run-off.* The water that sinks into the soil is called the *percolating water.* The run-off is greater in clay than in sand, on slopes than on the level, and in cultivated soil than in pasture or woodland. Clay gullies more easily than sand because the water cannot penetrate it so readily. Pastures and woodlands protected by the close ground cover are scarcely affected by a rain that may wash out the crops in cultivated fields. The water that enters the soil exists there in three forms, known as free, capillary, and hygroscopic water. *Free* water responds to the pull of gravity and goes downward until it reaches a point where the soil is saturated. *Capillary* water is not affected by gravity, but moves from moist to dry regions like a drop of water on blotting paper or the oil in a lamp wick. Much dissolved plant food is brought up from the subsoil by the capillary water, and the alkali in certain soils is due to the same cause. *Hygroscopic* water is not affected by either gravity or dryness. It clings closely to the soil particles and binds them into soil crumbs. It is present even in air-dry soils and roadside dust, but is not available to plants. Plants depend largely for their moisture on the capillary water in the upper layers of soil, though some of the free water deeper in the earth may return by capillarity. Water rises highest by capillarity in fine-grained soils. Clays and silts can lift water in this way from six to ten feet. In sandy soils water will not rise more than two feet.

The water table. The free water sinks downward until it reaches a point where all the spaces between the particles are filled with water, or where, as we say, the soil is saturated. This point is known as the *water table*, or permanent ground water. It now spreads out laterally and slowly drains off by seeping out of the soil at the edge of streams, lakes, and

swamps, or perhaps it may come to the surface, forming springs. In certain seasons, or in places where there is a stratum of impervious subsoil, there may be saturated areas above the water table that will cause tile drains to run. The real water table, however, lies deeper. It varies with the rainfall, rising in wet seasons and falling in dry ones. We dig our ordinary

Photograph by H. L. Hollister Land Co.

Fig. 22. One of the main laterals, or branches, of an irrigation canal

From this stream smaller channels lead to the separate fields

wells down into it, and in dry seasons they may dry up, owing to the lowering of the water table. The fluctuating water level may sometimes affect the character of mineral springs flowing from it, giving them an excess first of one mineral and then of another as the water comes in contact with different rock strata. Above ground a water surface is level, but in earth the water table curves upward under hills chiefly because the soil retards the downward progress of the free

water after a rain. Ponds and marshes are usually at the level of the water table.

Drainage. In the eastern United States it is estimated that there are a hundred million acres of swamp that could be rendered useful by drainage. All soils have to be drained before cultivated crops can be grown in them. The majority are drained naturally. Sand is often too well drained. When the saturated condition of the soil results from the seepage of water from higher levels, tile drains may be used to carry it away, but when the land lies very little above the natural drainage, tile drains would be useless and open ditches must take their place. Lands that are not permanently wet are often benefited by tile draining. The removal of the surplus water deepens the area into which the roots of plants can spread, warms the soil by admitting the air, and promotes further weathering of the subsoil. Draining wet lands may actually give the plants more water by increasing the area from which the roots can absorb, thus making them more drought-resistant. Drainage also makes it possible to begin the work on wet lands earlier in the spring.

Photograph by H. L. Hollister Land Co.

FIG. 23. A check gate in an irrigation ditch

This holds back the water and causes it to flow through smaller channels into the fields

Photograph by Mark Bennitt

Fig. 24. A field of wheat in the dry-farming region

Photograph by H. L. Hollister Land Co.

Fig. 25. Irrigating a fig orchard in California

Irrigation. Ordinary crops can be produced with as little as twenty inches of rainfall if it is properly distributed, but when it does not come in the growing season, or is limited in

amount, the lands must be irrigated if crops are to be grown. Many otherwise sterile soils are very fertile when water is applied. Irrigation, however, can be carried on only when the

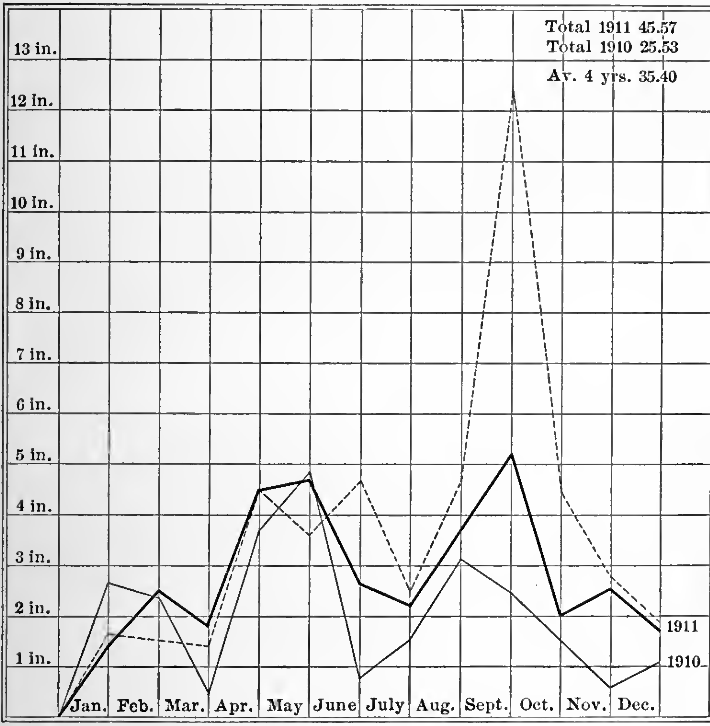

FIG. 26. Precipitation at Joliet, Illinois

The heavy line represents the average for the years 1908, 1909, 1910, and 1911. See page 45 for the precipitation by months. (Data supplied by F. M. Muhlig, United States Weather Observer)

land is properly located with reference to a permanent source of water supply. Usually some near-by lake or stream is selected, a dam built across it, and the water which falls in its basin stored for the use of the crops. From the dam, canals are made to run through the lands to be irrigated, and smaller ditches,

into which the water may be turned as needed, traverse the fields. Crops on irrigated land are usually certain, since the farmer is relieved from any dependence on the natural rainfall.

Dry farming. Twenty inches of rainfall, properly distributed, is about the minimum amount that will produce ordinary crops. In a few localities, where the rainfall is less, crops are produced by a system of *dry farming* in which the scanty moisture is stored up in the soil until there is sufficient for a

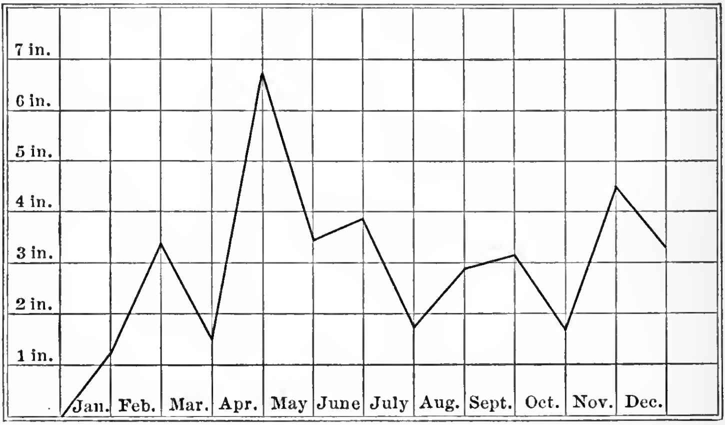

Fig. 27. Diagram showing precipitation at Joliet, Illinois, in 1909
Data supplied by F. M. Muhlig, United States Weather Observer

crop. This method consists in keeping the surface of the soil constantly loose, partly for the purpose of absorbing all the rain that falls, partly to prevent the evaporation of the water already in the soil. A crop may thus be grown every other year, or two crops in three years, the land remaining without a crop, though carefully tilled, during the intervening time. Crops have been grown by this method in regions where the rainfall is but twelve inches. In some cases it is possible to get a crop annually by cultivating the soil during that part of the year when it is not occupied by plants. The selection of drought-resistant plants may also facilitate dry farming.

Physiologically dry soils. A *physically* dry soil is one in which there is no moisture, but even in a soil containing much water, if the plants are unable to absorb it, it is *physiologically* dry to them. In winter, though the soil may be saturated, it is physiologically dry because the moisture is locked up in the form of ice. Strong salts or acids of any kind in the water may also prevent absorption. It is probable that many plants which grow in bogs find the soil physiologically dry to them, though at the same time it may be soaked with water.

PRACTICAL EXERCISES

1. Take two bottles of equal size and fill with roily water made by shaking up some clay with rain water or distilled water. Add to one bottle one tenth its bulk of a solution of lime and water and stand both bottles where they will not be disturbed. Examine at intervals to see which settles first, and explain the result.

2. Weigh out three samples of clay of 200 g. each. To one add 10 g. of slaked lime, to another add 10 g. of sand, and to the third add 10 g. more of the clay. Add enough water to make plastic and form into three balls. When these are thoroughly dry, pile weights, little by little, upon each until it is crushed. Explain the different effects of sand and lime.

3. Take four straight-sided lamp chimneys and fill one each with sand, clay, peat, and soil from the school garden. These materials should all be dry and well pulverized. Tie a piece of cheesecloth over the bottom end of each chimney and stand them in a rack, with the bottoms dipping into a shallow pan of water. In which does the water rise most rapidly? In which most slowly? Do you conclude that in drying they would follow the same order? Try it and see.

4. Visit the nearest barometer and barograph to learn how the pressure of the air is measured and recorded. Examine both centigrade and Fahrenheit thermometers.

5. Fill a glass with water, lay a sheet of writing paper over it, and holding the paper in place, quickly invert the glass. When the hand is removed, why does the water not run out?

6. Light a piece of paper, thrust it into a glass jar, and invert the jar in a shallow dish of water. Explain the action that takes place in the water.

7. Select two thermometers graduated alike and place them so that their bulbs only will be exposed to the sun. Cover one bulb with a white cloth and the other with a black one. Which thermometer now measures higher? How much? Explain.

8. Take the two thermometers and cover both bulbs with the same kind of cloth. Wet one cloth and leave the other dry. What difference do you now find in the way they register? Explain. Does fanning them have any effect upon the temperature registered?

9. Change 40° C. to Fahrenheit; 60°; 85°.

10. Change 68° F. to centigrade; 95°; 41°.

11. From the nearest weather observer find the average rainfall by months for the past five years. Plot the curve for the year as in Fig. 26, p. 51. The numbers at the left indicate the amount of rainfall in inches. What is the average annual rainfall of your region?

12. Plot the rainfall curve for the present year or for the preceding one. Is the rainfall well distributed through the growing season?

13. Make a similar curve for the average temperature by months for the past five years.

14. In a rainfall of half an inch how many cubic inches fall on an acre of ground? how many gallons? how many barrels? How many gallons fall on the school garden? on your own plot in it?

15. What is the total amount of water that fell on the school garden last month?

16. If an acre of ground is half pore space, how many gallons of water will be contained in the upper 7 in. when the soil is saturated?

17. From wells in the vicinity ascertain how far below the surface the water table lies.

18. Visit a marsh, hillside, or ledge of rocks, and decide what causes the water table to come to the surface here.

19. Visit lands that have been tile drained. Are there any other lands in the vicinity that would be benefited by the same treatment? Are there any lands that open ditches would serve better? any land where irrigation could be practiced to advantage?

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CHAPTER V

THE ORGANIZATION OF THE PLANT

The great plant groups. The vegetation of the earth consists of a bewildering variety of forms. At one extreme are plants consisting of a single cell and therefore lacking roots, stems, leaves, flowers, or fruits; at the other are the great trees, like the giant redwoods and eucalypti, which tower to the height of hundreds of feet and spread millions of leaves to the sunshine. Some species are adapted to live in ponds and streams, and spend their whole life immersed in water; others inhabit deserts in which rain rarely falls and moisture is at the minimum. Between these extremes all sorts of vegetable forms occur. Herbs, shrubs, vines, and trees vie with one another for

FIG. 28. Pteridophytes. A colony of walking ferns (*Camptosorus*)

a roothold and access to the light and air, while mosses, ferns, and fungi grow among and upon them. This great diversity of form makes it necessary to place the plants in different groups, according to their common characteristics, and botanists generally make four great groups of this kind. First and simplest in structure are the *Thallophytes*, comprising the algæ, fungi, and bacteria. None of these have true leaves or stems, or produce either flowers or fruits. Next above these come the *Bryophytes*, which include the mosses and liverworts. They are somewhat more highly organized than the thallophytes, but are like them in lacking true leaves, flowers, and fruits. The *Pteridophytes* consist of the ferns and their allies. These plants have stems and leaves, and some species bear structures that are essentially flowers, but none bear seeds. Last and most highly specialized are the *Spermatophytes*, or true flowering plants, which are distinguished from all the others by the production of seeds.

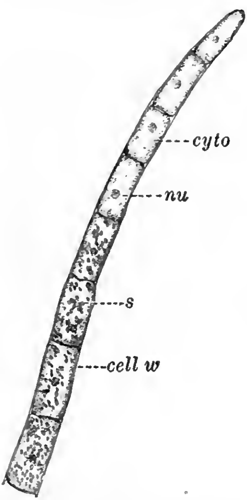


FIG. 29. An epidermal hair from the bracken showing the cells

cell w, cell wall; *cyto*, cytoplasm; *nu*, nucleus; *s*, starch grains

Only two of these groups are of much interest to the farmer and gardener. The thallophytes have to be taken into account because from their ranks come not only the bacteria that flavor cheese, butter, and other products, turn cider to vinegar, and render soils fertile, but also the multitudes of plant diseases and fungus pests that injure the cultivated crops, destroy our foods, cause disease in the lower animals, and even attack man himself. The cultivated plants, however, are spermatophytes, and so are the weeds that struggle with them for the possession of the soil. The word *spermatophyte*

means "seed plant," and this name was given to the highest group of plants in recognition of the way in which they are reproduced. All the other groups are developed from tiny one-celled structures called *spores*. These are individually too small to be seen with the unaided eye, but in masses are recognized as the black mold on bread, the smoke from puff-balls, and the like.

The regions of the plant. A typical flowering plant is often said to consist of root and shoot. The stem, however, is the real axis of the plant and bears all the other organs. It is present in the seed, and the first root grows from it; indeed, roots normally grow from stems, not stems from roots, as is popularly supposed. The root grows downward in the soil, holding the plant in place and absorbing necessary moisture and minerals. The shoot pushes up into the air from which it takes other necessary food material. In the leaves and other green parts of the plant these materials from both the earth and air are ultimately combined to form plant food by means of energy derived from sunlight. After a store of plant food is secured, flowers appear, and seeds are formed for the purpose of reproducing, multiplying, and distributing the species. These two functions, growth and reproduction, are common to all plants. During the early part of their existence the growth processes are in the ascendant; later, reproductive functions prevail.

Cellular structure of the plant. All parts of the plant are formed of minute boxlike structures called *cells*, which are usually much too small to be seen without the aid of the microscope. The ordinary undifferentiated cell consists of a semi-fluid, nearly transparent substance called *protoplasm* surrounded by a thin membrane known as the *cell wall*. Within the protoplasm are one or more spaces called *vacuoles* containing a watery fluid, the *cell sap*. Somewhere in the protoplasm, also, usually at one side of the cell, is a denser, darker part called

the *nucleus*. The nucleus is the center of the cell's activities. When a new cell is to be formed, the nucleus first divides into two equal parts and then the division extends outward to the surrounding cell wall. Soon there are two new cells in place of the original one, new walls having been constructed between them. These two cells now grow to maturity and are ready to repeat the process. All growth is essentially like this. When growing alone, the cell inclines to take a spherical shape, but in plant and animal tissues, where it is crowded on all sides, it becomes more or less

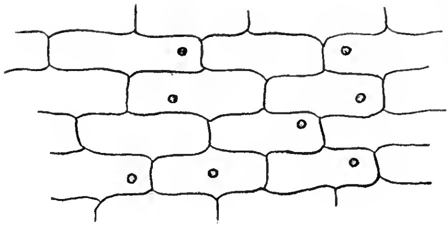
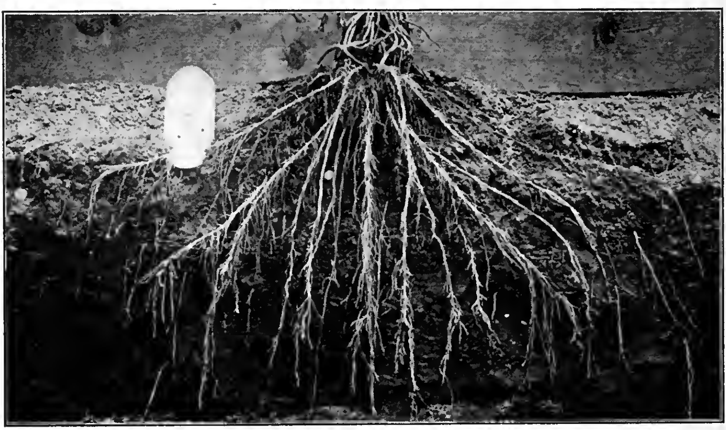


Fig. 30. Cells with nuclei from the epidermis of the onion bulb



Photograph by the United States Department of Agriculture

Fig. 31. The root system of the corn plant

angular. The cells in the woody parts of plants, in bark and the like, are very different from the cell just described, but all began as cells of this kind.

Roots. The root, or underground portion, of the plant is the first to put forth from the germinating seed. No matter in what position the seed may happen to be lying when growth begins, the root, in response to gravity, tends to grow straight downward, often curving considerably to do so. This is of great advantage to the young plant, since it quickly brings it into contact with the necessary moisture and other food materials, and also gives it a hold in the soil. The root, however, is not pulled down by gravity, but simply uses this force as a guide. After reaching the soil it may turn aside for moisture or food materials, or to avoid obstacles, such as stones, in the soil. In its search for moisture it often goes long distances. Instances are known where the roots of a tree have in this way filled drains three hundred feet away. Soon after penetrating the soil the first root begins to give off branches, and these branch and branch again, spreading out laterally and thoroughly exploring the soil for food materials. These lateral roots are often very numerous. A single corn plant may have enough roots to measure a quarter of a mile or more when placed end to end. In humid regions roots seldom descend more than four or five feet, but in arid regions they may go much deeper. The main root of such plants as mesquite, shepherdia, and alfalfa have been known to go down fifty or sixty feet in search of moisture.

FIG. 32. Wild hyacinth (*Camassia*) with multiple primary roots

Taproots. In a large number of species the main root continues to grow, becoming the main axis of the plant underground. Such a root is called a *taproot*. Frequently the taproot is used for the storage of food and is often much enlarged for this purpose. Good examples of taproots may be seen in the carrot, parsnip, and dandelion. All our root crops are cultivated for the food stored by the plant in the main or lateral roots. In some plants the first root fails to keep ahead of the others, and no taproot is found in mature specimens. The root system of the corn illustrates this. The onion, hyacinth, and other lilylike plants exhibit good examples of what are called *multiple primary roots*, where several roots of equal size arise together from the base of the stem. Plants with taproots are said to have an *axial* root system; without a taproot it is *inaxial*.

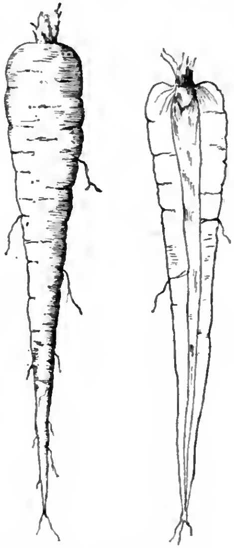


Fig. 33. Taproot of the parsnip

The sectional specimen shows the central cylinder and cortex

Structure of the root. The young roots of plants are alike in all essential particulars. In the center is a somewhat fibrous portion known as the *central cylinder*, and surrounding it is a softer layer, the *cortex*. On the outside is a thin skin formed of waterproof cells, which is known as the *epidermis*. The central cylinder has a series of small tubes, or *ducts*, running lengthwise through it, and it is along these ducts that the water absorbed by the plant travels upward. Roots that continue to live for some years, annually spreading into wider territory and absorbing a greater amount of food material, need a larger number of ducts for transporting these

substances. The new ducts are provided by a ring of growing cells, called *cambium cells*, that originate just inside the cortex and encircle the central cylinder. The cambium may also add other fibrous and corky cells to the cortex, and in time these form the bark seen in the roots of old trees. The activities of the cambium, therefore, result in increasing the diameter of the root from year to year, but growth in length takes place at the tip of the root only, and never at the base, as is generally supposed. If growth in length occurred at the base of the root instead of at the tip, the whole root would have to be pushed through the soil, a task which the plant would soon find impossible of accomplishment.

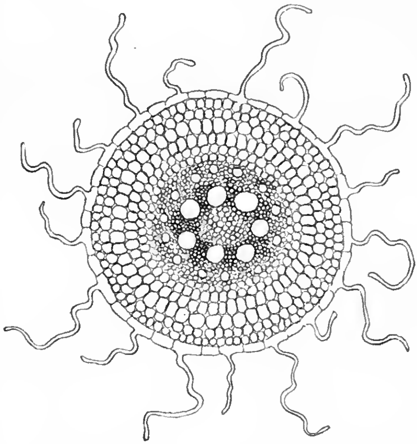


FIG. 34. Enlarged cross section of a young root showing epidermis, cortex, and central cylinder

The large openings in the central cylinder are the ducts. Note the root hairs growing from the epidermis

In the wild state the seeds of plants are scattered on the surface of the soil and germinate without getting very far below it, but at maturity we commonly find the base of the stem, or even the whole stem, some distance underground. In many cases this burial of the stem is due to the contraction of the roots. These penetrate the soil, and, after becoming established, contract and pull the plant downward. The contraction is mainly in the central cylinder and results in wrinkling the cortex. Such contraction wrinkles are well shown in the roots of the skunk cabbage or the iris.

Root hairs. Roots do not absorb through all parts of their surface, as is commonly supposed. The waterproof epidermis prevents the passage of moisture through all the older parts, and only a small portion near the tip, where there are special structures, called *root hairs*, designed for the purpose, is able to perform this office for the plant. At first glance a waterproof epidermis might seem a disadvantage to the plant, but its utility is seen when we learn that it serves to prevent moisture once absorbed from passing out into the soil again. The root hairs are tiny tubes closed at the end, which project from a zone of epidermal cells just back of the root tip. As the root adds to its length, new root hairs are developed on the side of the zone toward the growing point, while on the other the old ones slowly shrivel and disappear. The advancing root is thus always provided with a zone of fresh root hairs with which to absorb. On seedlings that have been sprouted in moist air the root hairs appear like a fine white down. They are very numerous and spread out in all directions among the soil particles, affording a much larger surface for absorption than would the epidermal cells alone. As the roots push onward through the soil the development of fresh root hairs constantly brings the plant into contact with new sources of food materials.

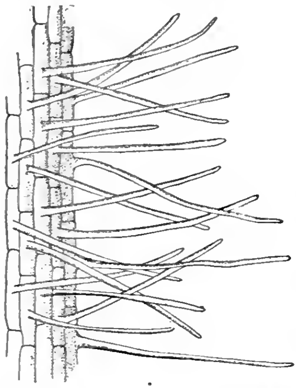


Fig. 35. A bit of epidermis with young root hairs. (Enlarged)

Fig. 36. A single root hair projecting from an epidermal cell. (Much enlarged)

Osmosis. Root hairs absorb from the soil by a physical process known as *osmosis.* In this, when two liquids of different densities are separated by a membrane, such as a cell wall and its lining of protoplasm, there is at once set up a tendency for each liquid to pass through the membrane to the other until both liquids are of equal density. In osmosis the current from the less dense liquid into the denser is always the stronger. One can illustrate the process very well by filling a small jar with molasses and tying a piece of parchment paper or hog's bladder over the open end to represent a cell, and immersing this jar in a larger jar of clear water for a few hours. If care has been taken to make a water-tight joint between the jar and its parchment cover, sufficient clear water will pass through the membrane into the molasses to distend the covering of the jar to its utmost. In the plant the evaporation of water from the leaves or its use in forming plant food renders the sap in the cells more dense than the soil water, and this consequently flows into the plant, carrying the dissolved minerals with it as these processes continue. Once in the root, the water spreads from cell to cell through the cortex until it finally reaches the ducts in the central cylinder and is sent upward to the shoot. The root hairs not only absorb the water that clings to the soil particles with which they come in contact, but this absorption sets up a capillary movement which drains adjacent particles of their moisture. If there should happen to be a large enough amount of any soluble substance in the soil, the current of water would set outward from the plant and cause its death. This is what happens when we put salt upon weeds or grass, and explains why ordinary plants cannot live in alkali soils.

The stem. For convenience the shoot may be divided into stem and leaves. The flowers, which at first might appear to belong to a third division, are really homologous with leaves and frequently show the relationship by becoming leaflike.

In the green rose all the petals of the flower revert to leaves. Stems are of most varied forms: in forest trees, tall, strong, and enduring for centuries; in the herbs, low, weak, and lasting but a single season. In the crocus the stem is reduced to a short, thick, and solid mass; in the onion it is a platelike disk at the bottom of the bulb; in the dandelion and the first-year plants of many other species it is a collarlike organ at the top of the root; and in Solomon's seal and iris it is a thick, elongated, subterranean, rootlike structure. In every case its chief functions are to properly expose the leaves to the light and to

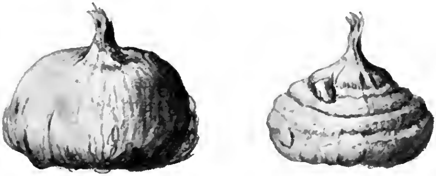


FIG. 37. Corms of the gladiolus

The right-hand figure shows the leaf bases removed. The corm is a form of stem

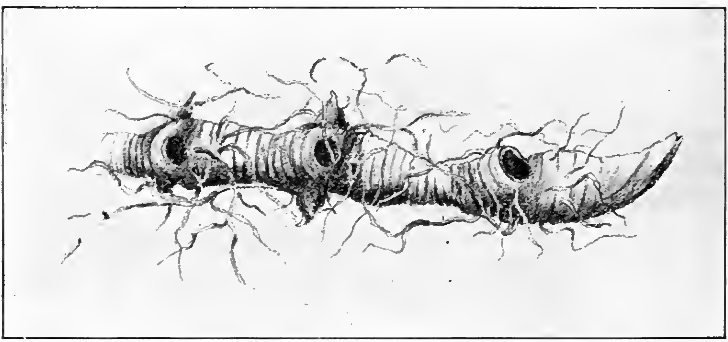


FIG. 38. The rootstock or rhizome of Solomon's seal

An underground stem. The dark spots are branch scars

transport foods and food materials. Short-stemmed plants gain illumination by spreading out their few leaves close to the earth in rosettes; others may send up a tall column with many branches, upon which multitudes of leaves are hung; while between these extremes are many different forms.

Structure of the stem. The stem, like the root, has a central cylinder and a cortex. When young it also has an epidermis, but in perennial stems this soon gives place to the outer *bark*, which serves the same purpose. The central cylinder is made

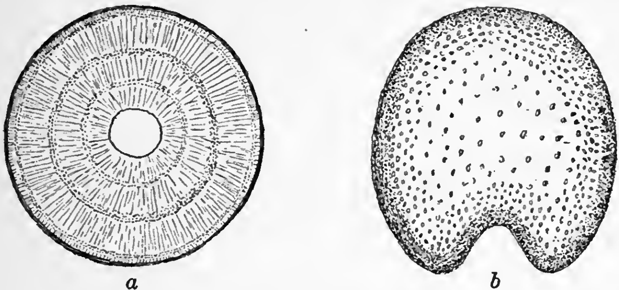


FIG. 39. Structure of stems

a, basswood, a dicotyledon; *b*, corn, a monocotyledon

up of many thin-walled cells, called *pith cells*, through which run strands of heavier fibers and two sets of tubes which form the *fibrovascular bundles.* It is the woody tissue of these fibrovascular bundles, packed closely together, that gives the trunks

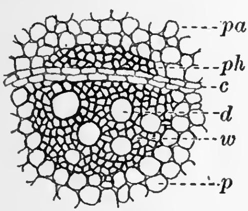


FIG. 40. A single dicotyledon bundle. (Much enlarged)

pa, parenchyma; *ph*, phloëm; *c*, cambium; *d*, ducts; *w*, wood; *p*, pith

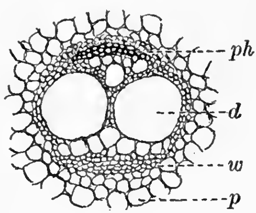


FIG. 41. A monocotyledon bundle. (Much enlarged)

ph, phloëm; *d*, ducts; *w*, wood; *p*, pith

of trees their great solidity and strength. Plants that live but a single season and rise only a short distance above the earth do not need to develop these bundles so extensively, though some are always necessary.

The way in which the bundles are arranged in stems makes it possible to separate the flowering plants into two very natural groups. In one, called the *monocotyledonous* group, these bundles are scattered throughout the central pith. A cornstalk or an asparagus stem is a good example of this. In the other, known as the *dicotyledonous* group, the bundles are arranged in a circle. The sunflower or any of our forest trees illustrates this type. The dicotyledons are further distinguished by the presence of a ring of cambium, which cuts through each bundle in the circle and separates the two sets of tubes. The part of the bundle inside the cambium is the *wood* and its tubes are *ducts;* the part outside the cambium is *bast*, or *phloëm*, and its tubes are called *sieve tubes.* Water and food materials pass upward through the ducts, but elaborated food is transported downward through the sieve tubes. The wedges of pith that extend outward

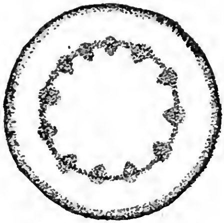


Fig. 42. Cross section of young dicotyledon stem showing the circle of fibrovascular bundles

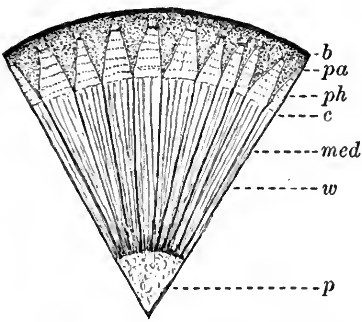


Fig. 43. Part of a cross section of year-old basswood twig

b, bark; *pa*, parenchyma; *ph*, phloëm; *c*, cambium; *med*, medullary rays; *w*, wood; *p*, pith

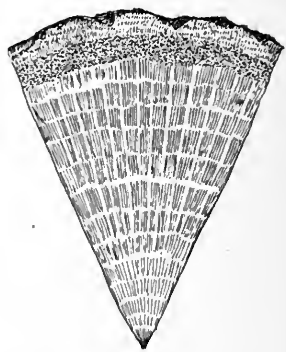


Fig. 44. Section of oak wood showing the annual rings and medullary rays

between the bundles are called *medullary rays*. These serve to transport foods across the stem. The activities of the cambium annually add new layers to both the wood and bast. In consequence dicotyledon stems yearly increase in diameter. In the new wood new ducts are also formed, and these circles of ducts serve to distinguish the wood of one season from that of another.

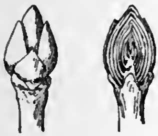


FIG. 45. Lilac buds

The sectioned specimen shows the embryo leaves and stem

Monocotyledons, on the other hand, lack cambium and commonly do not increase in diameter after the stem once starts upward. Externally the two groups also present several noticeable differences. The monocotyledons have more conspicuous joints, seldom branch, and, since they lack a cambium, have no bark. Among the well-known monocotyledons are sugar cane, rice, wheat, and all the other grains and grasses, as well as such plants as the lily, iris, and tulip. Our fruit and forest trees and most of our garden plants are dicotyledons.

FIG. 46. Naked buds of viburnum

Buds. All ordinary stems increase in length at the tip. At this point the rudimentary stem is crowded with undeveloped leaves, forming what is known as a bud. In woody plants, in addition to this *terminal* bud, other growing points may develop along the sides of the stem, late in the growing season, from which new twigs or flowers arise the following year. These are called *lateral* buds. They always occur at the joints of the stem and just above a leaf. Extra buds, called *accessory* buds,

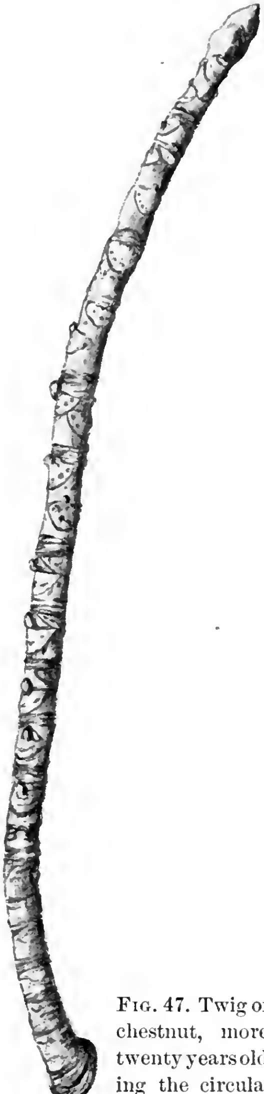


Fig. 47. Twig of horse-chestnut, more than twenty years old, showing the circular scars which mark the position of former bud scales. (Reduced about one half)

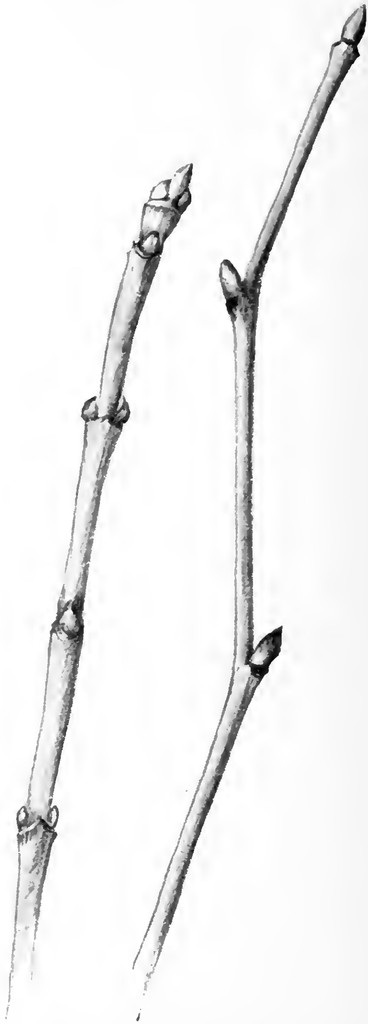


Fig. 48. The two types of bud arrangement, opposite and alternate

are often found with the lateral buds. These usually produce flowers. When growing points originate elsewhere, as on injured roots and stems, they are called *adventitious* buds. As the end of the growing season approaches, the stem ceases to elongate, and the buds prepare for winter by developing various devices intended to protect them from the effects of the cold. *Bud scales*, formed from the outer layers of leaflike parts, are usually developed, though some buds pass the winter without them. In many species the buds are further protected by coats of hair within the scales or by a kind of varnish on the outer parts. Others are almost covered by the bark of the twig during winter. Buds which are not protected by bud scales are called *naked* buds.

FIG. 49. Accessory buds of box elder (*Acer*)

FIG. 50. Accessory buds of the butternut (*Juglans*)

FIG. 51. Accessory buds of the golden bell (*Forsythia*) These are flower buds

On the return of spring the bud scales that are too hard to function as leaves are cast off, the stem begins to lengthen again, and the rest of the bud scales develop into leaves. The lateral

buds may also grow into twigs or flowers, but many of them usually fail to develop. They may remain alive, however, but continue in a resting condition, lengthening just enough each year to avoid being covered by the new wood and bark. Such buds are called *dormant* buds and are able to grow out to form twigs if the other twigs are injured.

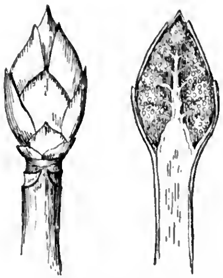


Fig. 52. Flower bud of the buckeye (*Æsculus*)

The horticulturist often classes buds as *leaf buds* when they contain only leaves, *flower buds* when they produce flowers only, and *mixed buds* when they contain both leaves and flowers. Flower buds that are formed in autumn are usually larger and different in shape from leaf buds, and by these characteristics they may be distinguished even in winter and the crop anticipated.

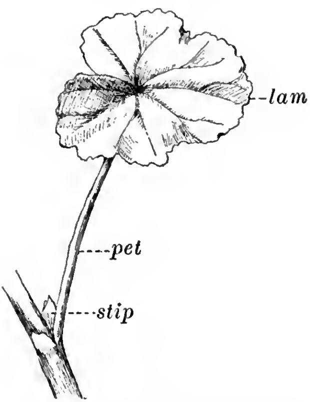


Fig. 53. A leaf of geranium
lam, lamina, or blade; *pet*, petiole; *stip*, stipules

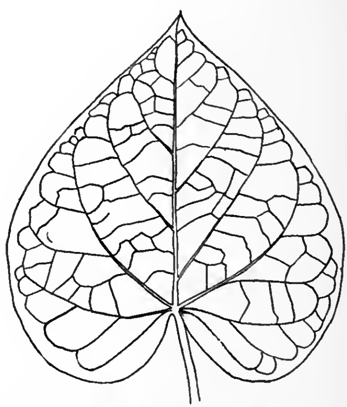


Fig. 54. Morning-glory leaf showing arrangement of the veins

Leaves. The leaf is essentially an expanded part of the stem, whose chief function is to make food for the plant from the gases in the air and the water and minerals brought up

from the soil. The points upon the stem where leaves originate are called *nodes*, and the spaces between are *internodes*. Leaves occur singly or in pairs at the nodes. When complete a leaf consists of a flattened green portion, the *blade ;* a stemlike part, the *petiole ;* and where the petiole joins the stem, two earlike

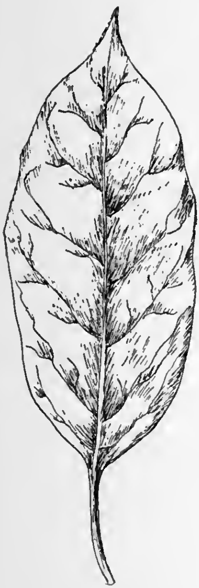


FIG. 55. Leaf showing pinnate venation

The geranium leaf on page 53 illustrates palmate venation

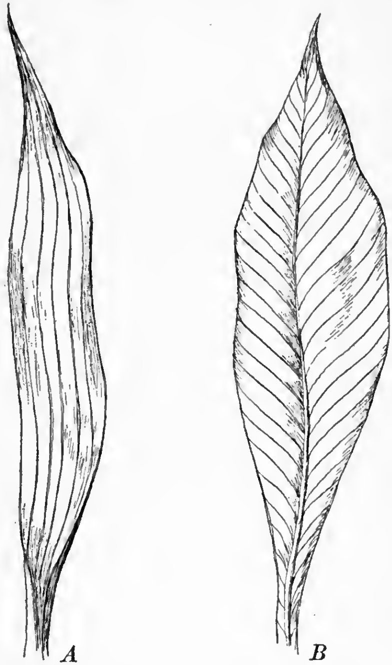


FIG. 56. Two forms of parallel venation

A, lily of the valley, veined from base to apex; *B*, canna, veined from midrib to margin

or strap-shaped green parts called *stipules*. The stipules are frequently absent, or they may take the form of spines or tendrils. Ramifying through the blade are strands of heavy tissue called *veins*. These are really fibrovascular bundles which serve to distribute food materials to the cells and aid in keeping the blade expanded. Monocotyledons and dicotyledons

may usually be distinguished by the difference in the veining of the leaves. In the monocotyledons the main veins usually run parallel from base to apex or from midrib to margin, and all the lesser veins are parallel and joined to one another at the tips. This is called *parallel* venation. In the dicotyledons the venation is known as *reticulated* or *netted*. Here the small veins form an irregular network and the main veins either spread out through the leaf, like the fingers on the

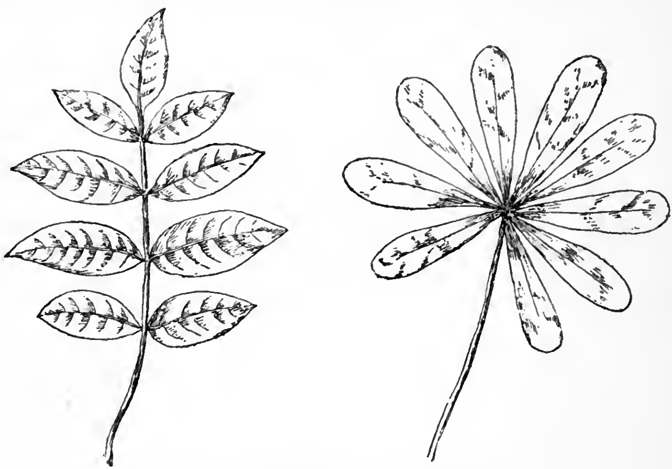


FIG. 57. Two types of branched leaves
The left figure is pinnately branched; the right, palmately branched

hand, in the form known as *palmate* venation, or they branch out from the midrib, forming the *pinnate* venation to be seen in the elm, dandelion, and others. There are also two types of *branched* leaves, the *palmately* and the *pinnately* branched, corresponding to the two types of venation in dicotyledons.

Internal structure of the leaf. Although the leaf blade is so thin, it consists of several layers of cells which show considerable differentiation in structure. In a cross section there may be distinguished an upper and lower layer of clear cells, forming the *epidermis*, between which are the layers of green cells

that give color to the leaf. The cells in the layer nearest the upper epidermis are closely joined together and are more or

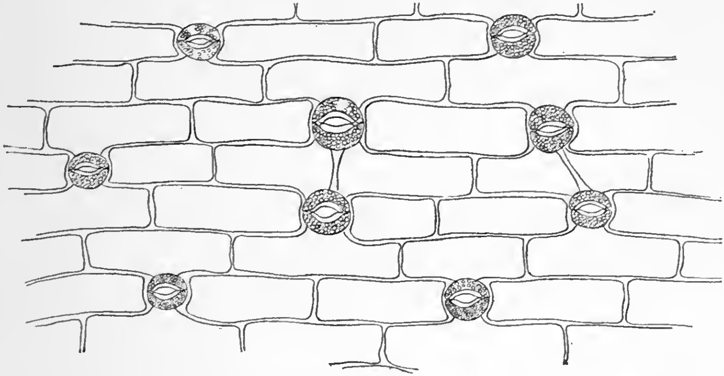


FIG. 58. Epidermal cells and stomata from the leaf of the amaryllis, a monocotyledon. (Much enlarged)

less elongated at right angles to the surface of the leaf, forming the *palisade tissue.* Below this layer the cells are more loosely joined to form the *spongy parenchyma.* The openings

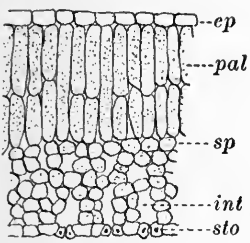


FIG. 59. Section through the leaf of the beech

ep, epidermis; *pal*, palisade tissue; *sp*, spongy parenchyma; *int*, intercellular spaces; *sto*, stomata

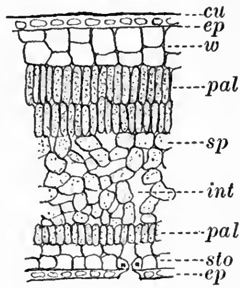


FIG. 60. Section through the leaf of the rubber plant

cu, cuticle; *ep*, epidermis; *w*, water-storage tissue; *pal*, palisade tissue; *sp*, spongy parenchyma; *int*, intercellular spaces; *sto*, stomata

between these cells are known as *intercellular spaces.* The epidermal cells are nearly air and water proof, and to facilitate the exchange of gases and water between the interior of the

leaf and the outer air, therefore, the epidermis contains great multitudes of tiny openings called *stomata* (singular, *stoma*), which connect with the intercellular spaces. Each stoma

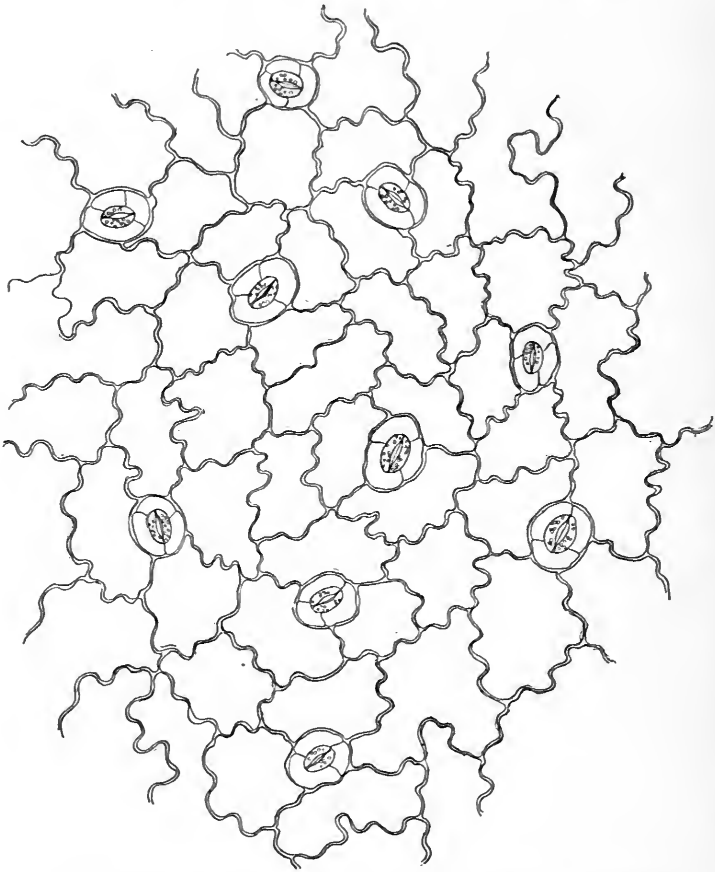


Fig. 61. Epidermal cells and stomata from the leaf of the begonia, a dicotyledon. (Much enlarged)

is provided with a pair of guard cells roughly semicircular in shape, which can, upon occasion, enlarge or diminish the size of the opening. The stomata are exceedingly minute,

but they make up in number what they lack in size. There may be several million in the epidermis on the underside of a single ordinary leaf. The stomata have been estimated to occupy nearly one twentieth of the area of the leaf. It is a curious fact that gases can enter the leaf through these minute openings more rapidly than they can pass through a single opening equal in area to all the stomata.

Formation of plant food. Food is formed only in the green cells of the plant. This is because the energy necessary for combining the food materials is derived from the sunlight by the green coloring matter called *chlorophyll*. In the cell this color is found in small bodies known as *chloroplasts*. The chloroplasts really form the food, though they are helpless without chlorophyll. The first food product formed is usually *grape sugar*, represented by the formula $C_6H_{12}O_6$, but this is soon turned to *starch*, a more stable form of plant food, with the formula $C_6H_{10}O_5$. Plants of the iris, lily, and amaryllis families rarely form starch. In such plants oil formed from the same three chemical elements may be the first visible product of photosynthesis. Starch, wood, and several other substances contain the same proportion of carbon, hydrogen, and oxygen, and the difference between them is accounted for by assuming a different multiple of the formula for each. The hydrogen and oxygen in the combination are derived from the soil water, and the carbon comes from the carbon dioxide in the air. The latter goes into the leaf through the stomata, and, spreading

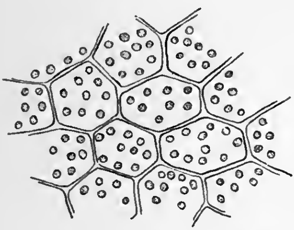


FIG. 62. Cells of a moss with chloroplasts

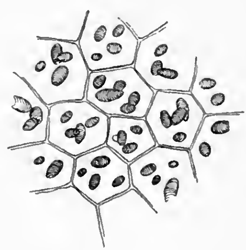


FIG. 63. Starch grains in the cells of a potato

through the intercellular spaces, mixes with the moisture in the cell walls and thus enters the cells. Here it is combined into food and the excess oxygen given off. The whole process is known as *photosynthesis.* It is popularly supposed that photosynthesis in plants is the equivalent of respiration in animals, but this is an error. Plants also respire, exactly as animals do, taking in oxygen and giving off carbon dioxide, but, unlike animals, they have the additional process of photosynthesis, in which carbon dioxide is taken in and oxygen released. The two processes differ also in other respects. Respiration occurs in every living cell, in roots as well as in stems and leaves, and goes on continually, while photosynthesis goes on only in the green cells in sunlight.

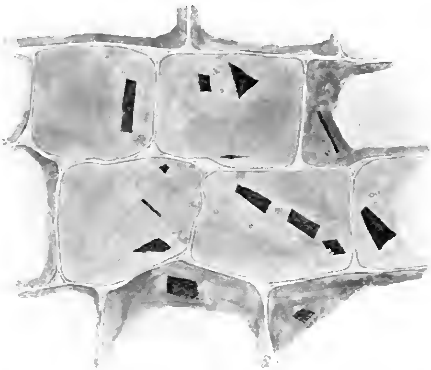


Fig. 64. Cells of the carrot with crystals of carotin, which give the root its orange color

The grape sugar formed in the leaves is, as we have noted, almost immediately turned to starch. Later, especially at night, this food is distributed through the plant, by way of the sieve tubes, to be used in the formation of new tissues, or it is stored in stems, roots, and other organs until needed. Starch, however, cannot pass through the cell walls, and before it can be moved it must be turned back to grape sugar again. This is accomplished by means of vegetable ferments called *enzymes*, and the process is called *digestion.* A green and starchy banana or pear laid aside for a time will become sweet by the same process. The underground parts of the plant are favorite places for the storage of food. Here the grape sugar is

again turned to starch by the *leucoplasts* or *amyloplasts*, small bodies allied to the chloroplasts. The leucoplasts and starch grains may be easily seen in young shoots of the canna.

Transpiration. Another important service performed for the plants by the leaves is the transpiration of water. The transpiration stream, passing off through the stomata, not only keeps the cell sap denser than the soil water, thus providing for a continuous inflow of food materials in solution, but the mere evaporation of so much moisture enables the plant to

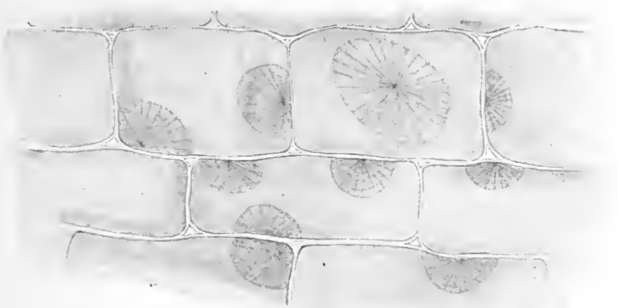


FIG. 65. Cells from a dahlia root, showing crystals of inulin, a substance allied to starch

keep cool in the midst of the downpour of heat on a summer day. At the end of the growing season most of our broad-leaved plants prepare for the approaching winter by casting their leaves. By so doing they avoid transpiration in winter when most of the moisture in the soil is locked up by the frost. But even in milder climates the leaves are eventually thrown off. In regions of summer drought they may all be cast at once; otherwise the individual leaves fall one by one, and the tree always has a crown of verdure. One reason for the casting of the leaves is that after a season of food making a considerable amount of useless mineral matter has accumulated in the leaf, which impairs its usefulness. The ashes from

a bushel of leaves picked from a tree in autumn are noticeably heavier than the ashes from a bushel of leaves picked from the same tree in spring. The growth of the stem and the

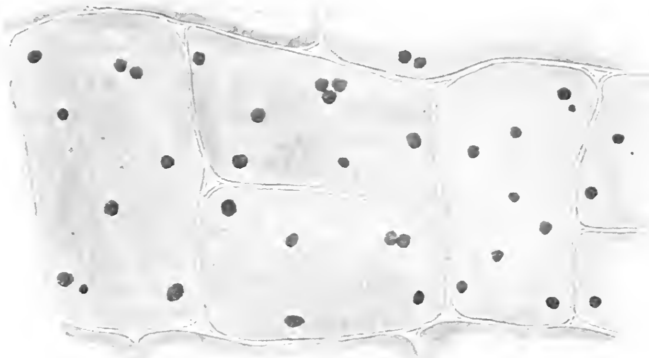


FIG. 66. Cells from the rind of an orange, showing the colored chromoplasts

production of new leaves which shade the older ones make it desirable to cut off the latter after a time. The fall of the leaf is caused by a layer of brittle cells which the plant constructs across the petiole. When the parts are cast off, a smooth scar is left, over which a thin cover of bark is deposited. Great numbers of flowers and embryo fruits are cut off by the plants in the same way, and many woody species also cut off some of their twigs. The latter are usually the young twigs of the season and of the same age as the leaves.

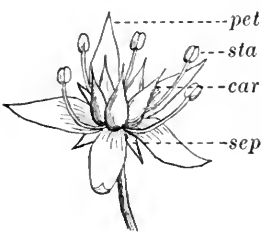


FIG. 67. Typical flower of the houseleek

pet, petals; *sta*, stamens; *car*, carpels; *sep*, sepals

The flower. When the season for reproduction arrives the flowers appear. These may be regarded as transformed branches designed for reproduction. The flower when complete has four sets of organs, called

respectively the sepals, petals, stamens, and carpels. On the outside are the green and leaflike *sepals;* next within are the colored and more delicate *petals;* then come one or more circles of threadlike organs with knobbed ends, the *stamens;* and last, occupying the center of the flower, are one or more bottle-shaped or club-shaped *carpels.* Taken collectively, the sepals form the *calyx* and the petals the *corolla.* The carpels when united form the *pistil*, though often the carpels themselves are called pistils. The base of the pistil is the *ovary* and within it are the *ovules*, destined to ripen into seeds. In order that fertile seeds be produced, however, it is necessary that the flower be *pollinated*, that is, that the tiny grains of *pollen* formed in the knobs, or *anthers*, of the stamen fall upon the *stigma* at the apex of the pistil. In this position each grain puts out a *pollen tube* which grows down through the substance of the pistil until it meets and enters an ovule, after which *fertilization*, or the union of an egg and sperm, is accomplished. Each flower, therefore, must receive at least as many pollen grains as it ripens seeds, and it usually receives many more, for some fail to reach the stigma and are therefore wasted. The end of the stem, from which the floral parts rise, is called the *receptacle.* When the other sets of organs in the flower appear to spring from the base of the ovary, the flower is said to be *hypogynous.* Sometimes the receptacle grows up about the ovary in such a way that the floral parts seem to grow from the top of the ovary. In such cases the flower is *epigynous.*

FIG. 68. A typical monocotyledon flower

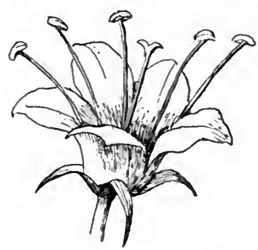


FIG. 69. A typical dicotyledon flower

Pollination. Stamens and carpels are the only organs in the flower that are necessary to the production of seeds, and for this reason are often distinguished as the *essential organs.* A considerable number of plants, of which the willow and cottonwood are examples, have only these two kinds of organs, showing very clearly that the others are not necessary. In some species the stamens and pistils are in separate flowers, as in the pumpkin and cucumber; in others they may be on separate plants, as in the willow. Even when both sets are found in the same flower, as in the lily and most of our common plants, they are usually separated from each other by a distance too great to be bridged without the aid of the wind, birds, insects, and other agencies. Of these, the two most important are undoubtedly wind and insects. Wind-pollinated flowers are generally inconspicuous, lacking sepals and petals and producing neither perfume, pollen, nor nectar, since the wind will work without pay; but flowers that depend upon insects and birds for pollination must provide a reward in the form of nectar or extra pollen, and must advertise it by

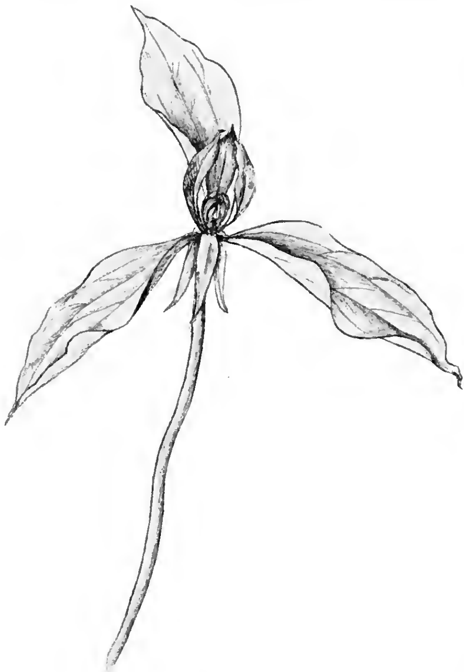


Fig. 70. Trillium

A plant in which the monocotyledon number (three) is especially prominent

FIG. 71. A group of wind-pollinated flowers

Those on the left are staminate; those on the right are of two kinds, the easily recognized staminate and the small starlike pistillate near the tips of the branches

perfume and brightly colored petals or sepals. These latter organs may also be of service to insect-pollinated flowers by being so arranged that visitors cannot remove the nectar

without being dusted with pollen and at the same time brushing off upon the pistil the pollen brought from other flowers. Many insect-pollinated flowers, in order to better direct the attention of insects to the nectar, have various colored lines and dots, called *nectar guides*, on the petals and sepals. In addition, the petals and sepals may protect the nectar from being dried up by the sun or diluted by rain and dew. In some flowers the stamens and pistils are so arranged that pollination may be effected by pollen from their own stamens. This is called *self* or *close pollination*. Usually, however, the stigma and stamens ripen at different times, or are so placed that pollen from another flower is required in order to produce seeds. When this occurs the process is called *cross pollination*. All the highly specialized flowers are adapted for cross pollination, and this arrangement has been found to produce more vigorous and versatile offspring. Wind-pollinated flowers have to produce a great abundance of dry, powdery pollen grains to insure that, when these are intrusted to currents of air, enough will find the waiting pistils to render their ovules fertile. Insect-pollinated flowers, on the contrary, having adopted a more certain method of transfer, do not have to produce so much pollen. In some species the flower contains only one or two anthers, and yet it finds this number sufficient for its needs.

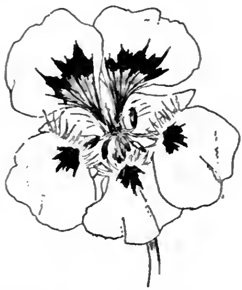


FIG. 72. Flower of the nasturtium (*Tropaeolum*), with two large nectar guides and three "false" nectar guides

False nectar guides are supposed to discourage the visits of small insects

In adapting themselves to insects and other agencies for the transfer of pollen, flowers have become more varied than any other organ of the plant. Running through all their variations, however, a general plan of the flower may be discerned. In

the flowers of monocotyledons there are normally three parts in each circle, or *whorl*, or if there are more than this, the number is some multiple of three. The iris has three sepals, three petals, three stamens, and a pistil composed of three carpels; the lily has three sepals, three petals, six stamens, and a three-parted pistil. The flowers of dicotyledons are usually distinguished from those of monocotyledons by having four or five parts in each circle, though they often exhibit a much wider range of variation.

Fig. 73. Plans of three typical flowers

The first a monocotyledon, the other two representing four-parted and five-parted dicotyledons

The fruit. The fruit results from the ripening of the pistil, or carpels, often in conjunction with other parts of the flower. Its development is one of the results of pollination. Flowers that fail to secure pollination are usually cut off and fall from the plant soon after blooming. There are many exceptions to this rule, however. All seedless fruits, among which may be mentioned navel oranges, seedless grapes, bananas, the currant of commerce, pineapples, and seedless or coreless apples and pears, must of course be produced without pollination. The secondary effects of pollination and the resultant fertilization are often far-reaching, and may extend not only to the ovary, or carpel, but to the receptacle and other parts as well. Fruits that develop as the result of incomplete pollination often lack the flavor of the seeded forms, and by their incomplete development indicate the fact that they have failed to receive sufficient pollen. In a majority of fruits the pistil alone is represented, as in peas, beans, plums, and tomatoes. In the apple, pear, and similar fruits the core, only, represents the pistil, the fleshy part being the receptacle that has grown up around it.

The fleshy part of the strawberry is also a receptacle, and all the seedlike parts upon it are the remains of tiny pistils,

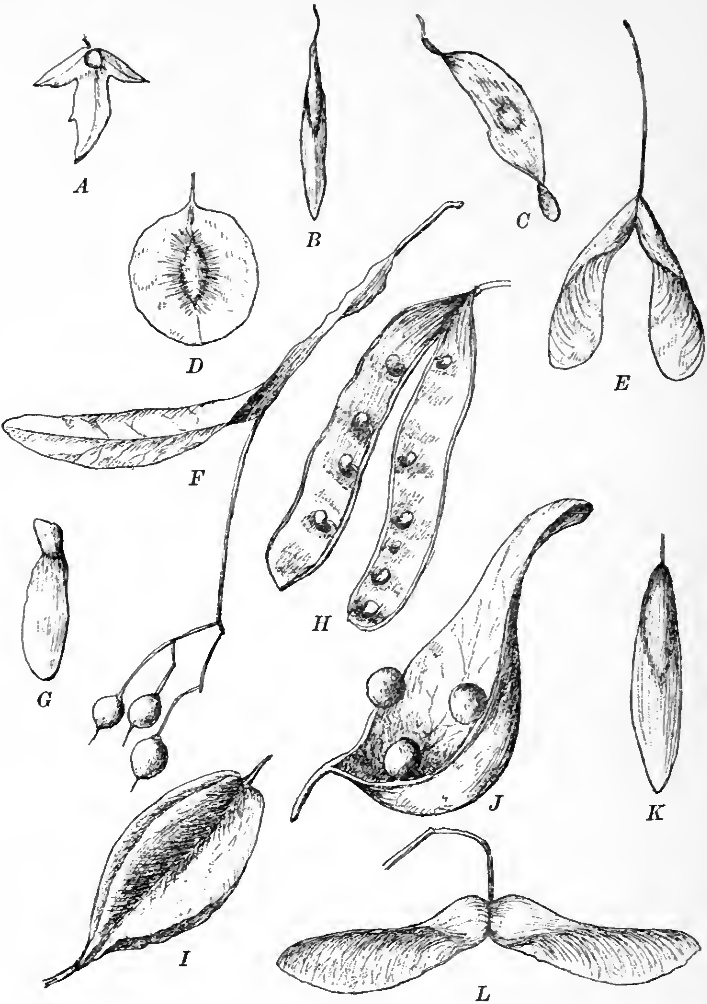


FIG. 74. Fruits modified for wind distribution

A, ironwood; *B*, white ash; *C*, ailanthus; *D*, hop tree; *E*, box elder; *F*, basswood; *G*, pine; *H*, locust; *I*, silver bell; *J*, sterculia; *K*, black ash; *L*, Norway maple

each consisting of a single carpel. In the blackberry each small pistil becomes fleshy and the receptacle serves merely to hold them together. The raspberry is somewhat like the blackberry, but when ripe the pistils separate from the receptacle. A few fruits, such as the mulberry, pineapple, and osage orange, are the product of several flowers and are called *compound* fruits. In the pineapple each "eye" represents a separate flower.

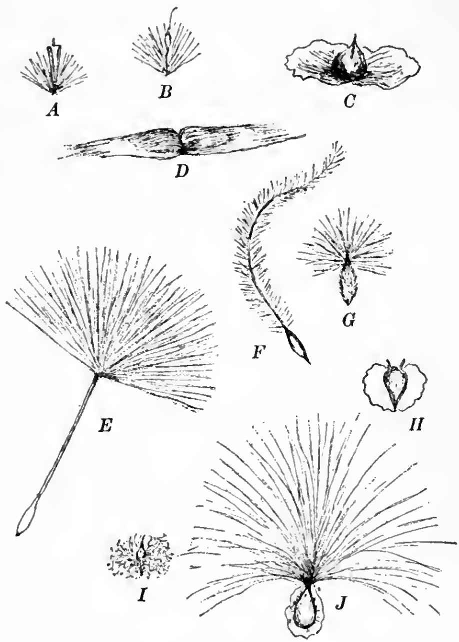


Fig. 75. Seeds modified for wind distribution

A, buttonwood; *B*, cat-tail; *C*, trumpet creeper; *D*, catalpa; *E*, dandelion; *F*, clematis; *G*, oleander; *H*, actinomeris; *I*, anemone; *J*, milkweed

The object of the plant in producing flowers and fruits is, of course, the continuation of the species by the formation of seeds. Many plants too tender to endure great cold or drought are able to form seeds that can do so, and thus the life of the species is carried over the unfavorable season. In addition, seeds may multiply and distribute the plants as well. The fruit is designed to protect the developing seeds and to aid in distributing them when mature. In some the fruit becomes sweet and juicy, to attract birds and mammals; in others it forms winglike sails, by means of which the seeds are carried long distances by the wind; in still others it develops hooks that

catch into the clothing of man and the other animals; while not a few shoot their seeds for some distance or in other ways provide for their dispersal.

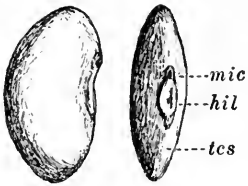


FIG. 76. External view of lima bean

mic, micropyle; *hil*, hilum; *tes*, testa

The seed. The seed consists of an outer covering, called the *testa*, within which is a young plant, or *embryo*. The testa is marked externally by a scar, the *hilum*, where the seed was attached to the parent plant. Near the hilum is a tiny opening through the testa called the *micropyle*. The embryo always consists of a stemlike part, the *caulicle*, to which are attached one or two seed leaves, or *cotyledons*. In most cases a tuft of very rudimentary leaves, a bud in fact, is found at one end of the caulicle. This is the *plumule*. The embryo is always provided with a food store sufficient to give it a start in life. In plants like the bean this food supply may be stored in the young plant or it may be stored within the testa but outside the embryo, as in the castor bean, in which case it is known as the *endosperm*, or *albumen*.

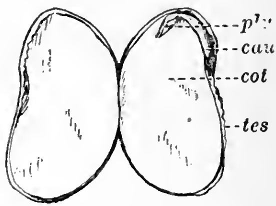


FIG. 77. Embryo of lima bean

plu, plumule; *cau*, caulicle; *cot*, cotyledon; *tes*, testa

FIG. 78. Seed of the castor bean, showing the projecting caruncle

So unvarying is the occurrence of either one or two cotyledons in each kind of seed that this fact is commonly seized upon to divide the world of flowering plants into two groups. The plants whose seeds contain only one cotyledon are called *monocotyledons*, and those whose seeds contain two are called *dicotyledons*. The differences between the groups, as we have seen, are not confined to the cotyledons alone, but are manifested in all the conspicuous parts of the plant.

Life cycle of plants. The life cycle of some plants is completed in a single season. They spring up, flower, produce their seeds, and disappear within the interval of a few weeks or months. On the other hand, some of the lofty trees that still inhabit the earth have been growing for many hundreds or even thousands of years. As regards their length of life, however, plants may be divided into three groups — annuals, biennials, and perennials. An *annual* is a plant that completes its life cycle within a year. This may occur during a single growing season, as in the radish, when it is called a *summer annual;* or the plant may spring up in autumn, live through the winter, and fruit in the spring, as in some varieties of wheat, thus becoming a *winter annual.* Several of the common summer annuals of our gardens may be treated as winter annuals. Lettuce and spinach are sometimes grown in this way. It is clear from the behavior of these plants that they do not die from the cold but are killed by fruiting. *Biennials* differ from annuals in that they require two growing seasons to complete the round of their existence. The first year they store up much food, which they use the second year in producing seeds. Carrots, salsify, and beets are biennials. In regions with a long growing season the line dividing annuals from biennials breaks down more or less completely.

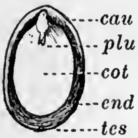


FIG. 79. Seed of honey locust
cau, caulicle; *plu*, plumule; *cot*, cotyledon; *end*, endosperm; *tes*, testa

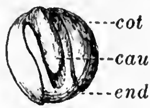


FIG. 80. Embryo of four-o'clock
cot, cotyledon; *cau*, caulicle; *end*, endosperm

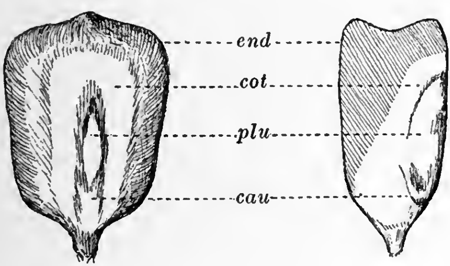


FIG. 81. Grain of corn
The fruit and seed of a monocotyledon. *end*, endosperm; *cot*, cotyledon; *plu*, plumule; *cau*, caulicle

FIG. 82. The showy lady's-slipper (*Cypripedium spectabile*)
A type of the highest monocotyledons

Perennials are plants that live more than two years. They are not killed by fruiting, though this makes heavy drafts upon their vitality. Like biennials, most perennials store up

more or less food in summer, which is expended in growth during the following spring. The rhubarb and asparagus, among garden vegetables, and the lily and iris, among decorative plants, are good examples of this. Most of the asparagus crop is produced from food made by the plant the preceding year. There are two classes of perennials. In the *herbaceous perennials* the stems die down to the ground in winter. Lilies, peonies, asparagus, and rhubarb are examples of this class. The *woody perennials* comprise our trees, shrubs, vines, and other forms that put up stems, which continue to live for a succession of years. *Trees* have a single trunk and usually attain heights of more than twenty feet. *Shrubs* have several stems and are less than twenty feet high. *Bushes* resemble shrubs, though they are somewhat smaller, usually being no taller than a man. *Vines* have stems too weak to stand alone and consequently must be supported by stronger plants. They may be *root climbers* like the poison ivy, *twiners* like the bittersweet, *true climbers* like the grape and woodbine, or *scramblers* like the climbing rose.

The rest period of plants. In perennial species, after a season of growth, the vegetative processes gradually cease, buds are formed, the leaves are thrown off, the wood cells thicken, and the protoplasm, excluding much of its moisture, goes into a resting condition. It is likely that this season of dormancy was originally in response to a change in the season, for in northern regions it occurs at the beginning of winter and in the tropics at the beginning of the dry season. A period of rest, however, seems natural to most plants. Many seeds refuse to grow if planted as soon as ripe; the spring flowering plants will not respond to warmth when brought into the house in early winter; and potatoes, onions, parsnips, and the like, stored in cellars, do not begin to sprout until the approach of spring. The hyacinth, narcissus, crocus, and tulip, after flowering in the open ground, ripen their foliage

and remain dormant during the summer, but in autumn begin to grow again, making more or less root growth all winter. The white, or Madonna, lily rests for a time in summer and makes new growth in autumn. Possibly half the species of crocus produce their flowers in autumn, and the witch-hazel is a well-known shrub with the same habit. Greenhouse plants, coming as they do from a region in which the season of rest is the dry season, are benefited by withholding water after the season for growth is over. Calla lilies and other bulbous plants are often allowed to become entirely dry after flowering. Our own plants seem to be adjusted to a season of cold for the rest period, though in many cases an exposure to dryness is as effective. In cold climates hardiness is often a matter of complete dormancy.

Genera, species, and varieties. Although each kind of plant has adopted the form most suited to its position in life, and in consequence has become different from all others, this has not resulted in a multitude of disconnected forms. Strong lines of resemblance run through the different groups, and, interwoven through the vegetable kingdom, bind it into one related whole. As a general thing, the more decided the resemblance between different forms, the closer the relationship. There are certain types of leaf and flower on which nature has rung a thousand changes, producing plant after plant essentially alike though ever varied. The casual observer does not fail to note these differences, and usually recognizes groups like the violets, lilies, asters, grasses, and legumes at sight, though he may fail when it comes to the lesser distinctions that separate species from species. The botanist, however, finds it convenient to carefully delimit these smaller divisions. To the unit of his classification he gives the name of *species* and defines it as a group of like individuals. All the plants of white clover or of field corn form a species. *Genera* (singular, *genus*) are groups of related species. Red

clover, white clover, yellow clover, and many other clover species belong to the clover genus, and all have a common resemblance in leaf, flower, and fruit. Going beyond the clovers, however, one finds many other plants whose general appearance suggests a relationship to them. Among these are beans, peas, alfalfa, vetch, locust, cowpeas, and soy beans. These differ enough to be put in different genera, but all are included with the clovers in a larger group called a *family*, which holds the same relation to genera as the genera themselves hold to species. The family to which the clovers and their allies belong is the Leguminosæ, or legume family. There are more than two hundred of these families, each composed of many genera and species. In a similar way families are grouped in *orders*. The legumes are placed with the rose-worts and various others in the order Rosales.

The species themselves, though called groups of like individuals, constantly exhibit minor differences that may be brought out by selection or by modifying the surroundings of the plant. The radish is a species, but cultivation has made many *forms* of it. Such forms the gardener calls *varieties*, but the botanist calls them *elementary species*. The cultivated cabbage has produced several striking elementary species or varieties, among which are included kale, collards, cauliflower, Brussels sprouts, and kohl-rabi.

Scientific names. Scientists have given each species of animal and plant a scientific name to facilitate handling it in literature, correspondence, and conversation. These names have usually been taken from the Latin or Greek and have the merit of being the same the world over — an obvious advantage when the common or popular name may change from one locality to another and is rarely the same in the tongues of different nations. In speaking to our neighbors we may use the common name only, but in dealing with strangers it may often be necessary to use the scientific name to avoid

being misunderstood. Each species has a specific name consisting of a single word, which is applied to it much as the given names of people are applied to them. Such specific names as *alba*, "white"; *rubra*, "red"; and *vulgare*, "common," are frequently used. The generic name, always written before the specific, shows to what larger group a species belongs. Thus the crimson clover is *Trifolium incarnatum*. The red clover is also a species of *Trifolium* called *Trifolium pratense*. Only one species in each genus can have the same specific name, though this may be used again and again in other genera. *Alba* is a common specific name for white-flowered species in many genera. The generic name, however, can be used for but one group of plants. There is but one genus *Trifolium* in all the world. In naming lesser divisions of a species it is customary to give them varietal names taken from the Latin or Greek, though in many cases such plants are named after prominent persons, gardeners, and the like.

PRACTICAL EXERCISES

1. Strip off a piece of epidermis from one of the scales of an onion bulb, mount, and examine with the microscope. Find and label all parts of the cell mentioned on page 57. In the cells of ditch moss or the hairs from the flowers of gloxinia or tradescantia, note the circulation of the protoplasm.

2. Make thin sections of a potato and examine in the same way, to see starch grains. Apply a drop of dilute iodine solution to a piece of laundry starch. Note the color. Test the mount of potato in the same way.

3. Mount a leaf of the ditch moss (*Elodea*) or a leaf from any of the broad-leaved true mosses and note the chloroplasts.

4. Mount thin sections of the carrot or orange peel and examine the chromoplasts. Make a similar mount of the epidermis from the underside of a nasturtium petal.

5. Soak seeds of radish or mustard for a short time and throw them against the inside of a clean moist flowerpot to which they will stick. Invert the flowerpot over a shallow dish of water for a few days and

an abundance of root hairs will be produced by the germinating seeds. Examine with the microscope.

6. Make longitudinal and cross sections of parsnip or carrot to see the regions of the root. Find, draw, and label the parts.

7. Make thin cross sections of any young root and examine with the microscope for the cellular structure.

8. Perform the experiment with osmosis described on page 63.

9. Peel one end of a potato, set the peeled end in a dish of water, make a hole an inch or more deep in the other end, and in this hole put some dry sugar. Explain the moisture that appears in the hole.

10. Cut slices of potato a quarter of an inch thick and place some in salt water and some in fresh water. Account for the difference in rigidity in the two sets at the end of an hour.

11. Make cross sections of cornstalk or asparagus and compare with similar sections of geranium, begonia, or any of our forest trees. Make sketches to show the differences noted.

12. In a thin section of begonia or geranium stem locate the pith, wood, ducts, bast, and cortex.

13. Get a thrifty young willow twig and girdle it by removing a ring of bark an inch wide two or three inches from the lower end. Stand this in water so that the girdled portion is covered. Where do roots appear? What light does this throw on the passage of foods and food materials through the stem?

14. On twigs of lilac, cherry, peach, golden bell, cottonwood, or horse-chestnut locate the flower and leaf buds.

15. Locate accessory buds in walnut, pipevine, red maple, box elder, butternut, and peach.

16. Select leaves to illustrate parallel, palmate, and pinnate venation. Make sketches to show the different forms.

17. With the microscope examine the epidermis from the underside of a leaf for the stomata. Draw.

18. In a thin cross section of a leaf locate the tissues described on page 72.

19. Thrust the petiole of a geranium leaf through a small hole in a piece of cardboard and place the latter so that the petiole of the leaf will dip into a glass of water. Over the blade of the leaf invert a drinking glass, which should rest upon the cardboard. Explain the presence of the moisture that forms on the upper glass in a short time.

20. Select a representative flower and locate the organs named on page 79.

21. Distinguish the monocotyledons from the dicotyledons in as many different kinds of flowers as you can find.

22. Locate the nectar guides and nectaries, if any, in barberry, buttercup, toadflax, catalpa, horse-chestnut, nasturtium, and phlox.

23. Decide whether the following were produced by hypogynous or epigynous flowers: apple, orange, banana, pear, cranberry, olive, and tomato.

24. Make a collection of seeds to show as many methods of seed dispersal as possible. Visit the nearest museum for other examples.

25. Find the two cotyledons in the bean and the single one in the corn. Examine other seeds to discover whether they are monocotyledons or dicotyledons. In which seeds do you find endosperm?

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CHAPTER VI

THE ELEMENTS NEEDED BY PLANTS

Source of the elements. The chemical elements indispensable to plants are ten in number; namely, oxygen, hydrogen, nitrogen, potassium, magnesium, calcium, iron, sulphur, phosphorus, and carbon. Several others have been found in plants, but these have been proved unnecessary by growing plants to maturity in media in which these elements were lacking. Although the ten elements indicated are all essential, most of them are taken in very minute quantities. The small amount of ashes left when wood is burned represents the mineral matter taken up by the plant in forming it, and much of this is likely to be silicon and other elements that are nonessential. Very little is known of the part played by some of the essential minerals in the economy of the plant. Possibly their presence acts simply as a stimulant for various plant processes. The only element taken entirely from the air is carbon. Oxygen is taken from the air for respiration, but that used in making food is taken combined with hydrogen as soil water. All the other elements are derived from the soil, in which they exist as compounds and not as single elements. These compounds are usually chlorides, carbonates, sulphates, phosphates, and nitrates. In most of these there is considerable oxygen, the termination *ate* in the names of the compounds indicating its presence. These materials are dissolved out of the soil by the soil water and carried into the plant by osmosis.

Selective absorption. Analysis of the ash of plants has shown that all the species of a given area do not contain the same proportion of the different minerals, though growing under

exactly the same conditions and absorbing the same soil water. Clover when growing with barley may take up five or six times as much lime as the barley does, while the latter takes up eighteen times as much silica as the clover. Similar differences in the absorption of food materials are found in other plants. It is as if each plant exercised a conscious selection. Such a condition, however, is to be explained on purely physical grounds by what is known as *selective absorption.* When minute quantities of any mineral are dissolved in the soil water, they will pass into the plant by osmosis, but in every instance each substance in the water acts with reference to similar substances in the plant as if it were the only element concerned. It follows, therefore, that if the plant happens to be using a certain substance, the depletion of the supply in the cells will induce more of it to filter in; but if the plant has no use for it, the density of the solution for this particular substance on both sides of the cell wall soon becomes equal and the osmotic action with reference to it ceases. Plants cannot exclude poisons and other harmful or useless substances when sufficiently diluted by the soil water.

Use of water to the plant. In addition to carrying the dissolved minerals into the plant, water forms a very essential part of the plant food, maintains the turgor of the cells and thus keeps the plant in shape, is the medium in which all the vital processes of the plant go on, aids in the transfer of food within the plant, and, finally, by its evaporation, serves to cool the plant and keep the cell sap denser than the soil water. The amount of water transpired by growing plants is remarkable. It is estimated that for every pound of dry matter produced by ordinary crops, from 250 to 400 pounds of water is transpired, while mustard is said to require 900 pounds of water for each pound of dry matter. A healthy apple tree has been estimated to transpire 35,000 pounds of water during the growing season. A moist spot may be drained through

the simple expedient of planting such water-loving species as willow and cottonwood in the vicinity. A great part of the living plant is water. Turnips, melons, and the like contain more than 90 per cent of water, and even in air-dry plants the amount is seldom less than 10 per cent. The amount of water may differ greatly in different parts of the same plant; thus the flesh of the watermelon, peach, plum, and the like contain much more water than the seeds or the vegetative parts of the specimen.

Root pressure. Most of the water given off by plants escapes through the stomata as water vapor, but occasionally, as at the close of a warm day in summer, the roots may continue to absorb more than the leaves can evaporate in the cool air of evening. This excess moisture may appear on the leaves as minute globules or even larger drops of water. Such excretion of water is called *guttation*, and the force exerted by the roots in sending it upward is *root pressure.* In some plants this force is very great. In the birch it is sufficient to hold up a column of water more than eighty feet high. It is root pressure that causes grapes to "bleed" when trimmed in spring, and the same force makes the sap run from wounds in trees. The drops of water to be seen on the leaves of such plants as nasturtium in the early morning are due to root pressure, and so is much of what passes for dew on grassy areas. Often the roots of weeds cut down by the hoe will continue to send up water for some time and show, by a moist spot in the dry surface soil, where each plant stood.

Carbon dioxide. The gas, carbon dioxide, though found in the atmosphere in so small an amount as three parts in ten thousand, is nevertheless the only source of the carbon in plants. In a ton of dry wood at least a thousand pounds is carbon, all of which has been derived from the air. The carbon in our hard and soft coals, peat, and the like was stored up in the same way and from the same source in other days. This

element is the characteristic element of all animal and plant life, as silicon is of the mineral kingdom, but the carbon fixed in any form of organic life is only one stage in a constant cycle of changes. Upon the death of the organism it is again united with oxygen by the processes of decay and liberated as carbon dioxide, only to be selected by new plants and formed into starch and plant tissues again. Though forming so small a proportion of the air, it is nevertheless estimated that there are 3,400,000,000,000 tons of it in the atmosphere — more than 25 tons for each acre of soil. In plants and animals carbon is most frequently found united with hydrogen and oxygen to form *carbohydrates*, a carbohydrate being defined as a substance consisting of these three elements, with the hydrogen and oxygen in the proportions in which they form water. Starch, sugar, wood, and cellulose are all carbohydrates.

Nitrogen. Four fifths of the air is nitrogen, but ordinary plants cannot use it. Their supply is derived almost entirely from the nitrogen in the humus of the soil. A few plants, to be described later, are able to make use of atmospheric nitrogen, but the rest use nitrogen only in the form of nitrates; that is, nitrogen combined with other elements, such as calcium, potassium, magnesium, sodium, and the like. One of the chief uses of these latter elements to plants seems to lie in their ability to combine with nitrogen in a form that the plants can use. Nitrogen is one of the elements most frequently lacking in soils, though there are not less than 35,000 tons in the air over each acre — worth about ten million dollars at present prices if it were only available for plants. Nitrogen intensifies the color of plants, increases the growth of leaves and stems, and, when abundant, may hinder seed formation by favoring growth processes. Some grain crops, when supplied with plenty of nitrogen, grow so luxuriantly that the stems are unable to support the weight of the plant. Nitrogen is also necessary for the formation of protoplasm and all other proteins.

Calcium and magnesium. Calcium and magnesium, which are much alike, are most familiar to us in limestone and dolomite. In addition to being useful in forming compounds with nitrogen that the plant can use, these elements form unions with various acids in the plant which would otherwise be harmful. Calcium is an important part of the chlorophyll and nucleus, and promotes the hardiness of plants. On soils containing much calcium or lime, plants endure drought and frost much better than in soils in which it is lacking. Certain plants, such as alfalfa, clover, peas, and beans, are often known as *lime plants* because they cannot exist in soils deficient in this element. Spinach, beets, lettuce, and many others cannot grow without lime. On the other hand, many plants of sandy and boggy soils are so sensitive to lime that they cannot endure even small amounts in the soil water. Magnesium is important in forming seeds, and its absence may not be noticed until flowers and fruits fail to develop. While absolutely essential to plant growth, magnesium in the absence of lime acts like a poison. Calcium is usually more abundant than magnesium in leaves and stems, but in seeds the ratio is usually reversed.

Potassium and phosphorus. Potassium is supposed to aid in the production and transportation of the carbohydrates and to reduce the acidity of cell sap. It increases the turgidity of the cell and hastens the ripening of wood and fruit. It also increases the plant's resistance to frost and is reputed to deepen the color of flowers and fruits. Certain plants contain so much potassium or potash that they are called *potash plants.* Phosphorus is associated with the production of proteins, and its lack prevents the development of seeds. Fleshy roots may also contain much potassium. When soils are deficient in this element the addition of sodium is followed by renewed plant growth.

Sulphur and iron. Sulphur and iron, so frequently found together in nature, are necessary constituents of protoplasm. Iron is also essential to the formation of chlorophyll in plants.

Chlorine, silicon, and others. Small amounts of chlorine, silicon, sodium, manganese, aluminum, and other minerals are usually found in the ash of plants. They are present in most soils and, being dissolved in the soil water, flow into the plant with it. Silicon is often abundant in the older, denser parts of plants, and the flinty exterior of scouring rushes and grass stems is due to it. The "shells" of diatoms and the stems of certain scouring rushes contain so much silicon or silica that the organic parts may be burned or dissolved out, leaving a perfect skeleton of the mineral. Silica, however, does not appear to be essential to the life of the plant. It was once thought that it was necessary to give strength to the stems of grasses and other plants, but this is shown to be a mistake by the fact that silica is often many times more abundant in the leaves of plants than in their stems. Some regard chlorine as essential, since it is usually present in the plant.

PRACTICAL EXERCISES

1. Take two geranium leaves and place one in fresh water and the other in a 10 per cent salt solution for half an hour. Explain the difference in the two.

2. Weigh a good-sized potato and thoroughly dry it by heating in an oven. Weigh again. What per cent of moisture did it contain? Place in a crucible and heat to redness to drive off the organic matter. What per cent is ash?

3. Thoroughly water a pot of young oat seedlings and turn a bell jar over them. Account for the drops of water that soon appear on the tips of the leaves. The same experiment may be performed with nasturtium or fuchsia plants if oats are not at hand.

4. Clover hay may yield three tons to the acre. How many inches of rainfall would be needed to supply the necessary moisture if none were wasted and the plants used 250 pounds of water in producing each pound of dry matter?

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CHAPTER VII

FERTILIZERS

The available mineral in the soil. The elements needed by plants exist in the soil in very unequal proportions. Some are so abundant as to be practically inexhaustible; others occur in such small quantities, or are so slowly weathered out of the soil, that cropping for a few years may deplete the supply to a point where more must be added before the land will again be fully productive. It has been estimated that in the upper seven inches of certain soils there is sufficient iron to produce a hundred-bushel corn crop every year for two hundred thousand years, and enough calcium, sulphur, and magnesium to produce such crops for from two thousand to fifty thousand years, but only enough nitrogen and phosphorus for from fifty to seventy years. Other soils may differ as to the amounts of each element they contain, but the proportions are likely to be about as given here. It is thus seen that the soil is not an indestructible asset, but that it may easily wear out by having all its store of certain elements abstracted by growing crops. Nor is it necessary that an element be entirely lacking in a soil to render it unfertile. If the element be in a form that is not available to plants, the effect is the same as if it were entirely absent.

Toxic substances in the soil. Occasionally an analysis of the soil may show that it contains sufficient food materials for good crops, yet the plants that grow upon it do not flourish because of certain substances excreted by the roots of the plants themselves, which seem to be toxic or poisonous to that particular crop. When crops of one kind are grown for

several years in succession upon the same land, for instance, the yield begins to decrease long before the available mineral food has been used up. Thrifty crops of the same kind growing elsewhere, if watered with extracts from such soils, give every evidence of having been poisoned. When supplied with certain chemical elements, however, they regain their health. Many wild plants exhibit similar peculiarities, and their

Photograph by the University of Illinois

FIG. 83. Wheat crop averaging 9.6 bushels to the acre

The soil has been limed and a crop of legumes plowed under. Compare with the following figure

inability to grow in the same soil for any length of time is attributed to an increase of the toxic elements. After growing for a year or so in a given spot the old parts die, while the new ones move out from the center in a constantly widening circle known as a "fairy ring." Such rings are more common in fungi, lichens, and ferns, but they also occur in flowering plants. Most of these poisonous excretions appear to be harmful only to the species that produced them, which explains one of the benefits of a rotation of crops. By growing different crops on

the land the toxic substances excreted by one kind have time to escape or become neutralized before the same crop is again grown there. In some cases, however, the excretions from one set of plants seem harmful to others. The butternut tree has been found antagonistic to the shrubby cinquefoil that sometimes infests the pastures in New England and elsewhere,

Photograph by the University of Illinois

FIG. 84. Wheat crop averaging 21.5 bushels to the acre

This wheat was grown on land adjoining that shown in preceding figure. In addition to lime and legumes the soil has had an application of phosphorus

while a similar antagonism seems to exist between grass and certain fruit and shade trees. Additions of various substances to the soil seem to neutralize these poisonous excretions of plants and enable them to continue in vigorous growth. Some contend that this is the only value to be derived from fertilizers. Whatever the reason for adding fertilizers, the fact remains that good crops cannot long be produced without them. Nor will an excess of one needed element compensate for the

lack of another; a sufficient amount of each must be present. Often supplying a single lacking element in the soil will more than double the returns from the crop.

Elements that may be lacking. Soils are seldom deficient in sulphur, iron, or magnesium, and calcium is usually abundant enough, though it may sometimes be lacking even in soils derived from the weathering of limestone rocks, because it is easily dissolved and carried off by the water. Phosphorus, nitrogen, and potash, however, belong to a different category. They are seldom abundant in any soil and are so rapidly removed by crops that the lack of one of them is usually the cause of a decreased yield. Soils may be analyzed by the chemist and the exact amount of each mineral constituent determined, but there are various ways of making the plants themselves tell what essential element is lacking. One of the best methods of determining this is to make ten plots, side by side, in soil as nearly uniform as possible, and add to each plot a different fertilizer or combination of fertilizers containing the elements likely to be lacking. The usual arrangement is as follows:

Plot 1. Nitrogen as nitrate of soda at the rate of 160 lb. to the acre, or dried blood at the rate of 700 lb. to the acre.
Plot 2. Potash as muriate of potash at the rate of 80 lb. to the acre, or potassium sulphate at the rate of 200 lb. to the acre.
Plot 3. Phosphorus as acid phosphate at the rate of 320 lb. to the acre, or bone meal at the rate of 200 lb. to the acre.
Plot 4. Calcium as lime at the rate of 40 bu. to the acre.
Plot 5. Nothing. This plot serves as a check for comparison.
Plot 6. Nitrogen and potash in the proportions given above.
Plot 7. Nitrogen and phosphorus in the proportions given above.
Plot 8. Potash and phosphorus in the proportions given above.
Plot 9. Potash, phosphorus, and nitrogen in proportions as above.
Plot 10. Same as Plot 9 with the addition of lime.

The crops to be tested should be sown across all the plots, and will soon show which element is deficient by a more thrifty growth in the plot containing this element. It is desirable that

different crops be used in the test, since the lacking element may not be the same for each. In any soil the need for calcium may be easily discovered by treating part of a field with lime and comparing the treated area with the part not treated. The lime should be applied at the rate of twenty bushels or more to the acre. When red clover and alfalfa grow well on a given soil, this is a good indication that it contains sufficient calcium. A growth of mosses indicates a lack of this element.

Sources of the needed elements. It is only in exceptional cases that the cultivator concerns himself about any element in the soil except potash, nitrogen, and phosphorus. These three are seldom abundant, and the farmer always adds fertilizers containing them when they can be cheaply obtained. Stable manure is called a "complete" fertilizer because it contains portions of all three. Before the advent of the white man the Indian had discovered the value of fish as a fertilizer. Near the coast it was the custom to place a fish in each hill of corn. In many places fish is still used for fertilizer. Several other available sources of the necessary elements exist. *Nitrogen* is found in guano, fish guano, dried blood, slaughter-house waste, bone meal, linseed and cottonseed meal, ammonium sulphate (a product of gas works), potassium nitrate, and sodium nitrate, or Chile saltpeter. The sodium nitrate is the most soluble. *Potash* is found in wood ashes, muriate of potash, sulphate of potash, and kainit. *Phosphorus* occurs in bones and bone meal, phosphate rock, and Thomas slag, which is a by-product in the manufacture of steel. When necessary to apply calcium it may be in the form of ground limestone, quicklime, marl, gypsum, shells, and bones. In applying fertilizers it is well to remember that some are more soluble than others and, applied in too great quantity, may easily make the soil water so dense as to kill or greatly retard the plants it was designed to help. Other fertilizers, becoming available more slowly, may not show their effects upon the crops until the second season.

Manures. The word *manure* comes from the Latin word *manus* meaning "hand." The reason for the derivation is seen when it is known that to manure originally meant to dig or cultivate by hand. Thus in Defoe's "Robinson Crusoe," written in 1719, we find the expression, "The ground that I had manured, or dug up, for them was not great." Digging about the plant was early found to make it more thrifty, and the old farmer's maxim that "tillage is manure" is true in a more literal sense than he perhaps imagines. When it was found that adding various matters to the soil had the same effect upon the plants as cultivation, these substances soon gained the name of "manures."

Green manures. Frequently the cultivator plows under a growing crop for the purpose of adding humus and its contained nitrogen to the soil. Such additions are known as *green manures.* Barley, turnips, and similar crops, and even weeds, may be used for this purpose, but clover, alfalfa, and other legumes are usually relied upon. These latter bear upon their roots numerous small nodules containing bacteria which are capable of fixing atmospheric nitrogen in the soil, and are therefore especially valuable for such purposes. Legumes actually leave the soil in better condition than they find it.

Nitrification. Undoubtedly the most important single element of plant food is nitrogen. This element is not found in combination in the rocks because it is too inert to readily combine with other elements, and the large quantities in the air are not available to ordinary plants, though some species are believed to be able to absorb nitrogen from the ammonia in the air through their leaves. Small amounts of both ammonia and nitric acid may be added to the soil by being brought down from the air in rain water or snow and converted into plant food by the soil bacteria, but the amount thus added to the soil is too insignificant to make it important as a source

of nitrogen to plants. Practically all the nitrogen used by plants comes from the humus in the soil. Nor can the plant use all the combinations of nitrogen derived from humus. In the soil this element may exist as ammonia, nitrites, and nitrates, but plants can use only the nitrates.

Bacteria and nitrification. The changing of nitrogenous substances in the humus to forms that are available to plants is accomplished by bacteria, of which there are some fifty million in every cubic centimeter of rich soil. These bacteria are the smallest of living things. They are most numerous near the surface of the soil, but are found in lessened numbers as far down as the lowest layers of the subsoil. Like other plants, they need warmth, moisture, and oxygen for growth, but, unlike them, must have organic food. They are very intolerant of acids and will not live in sour soils. In bogs and other water-soaked soils the absence of air prevents the growth of bacteria, the soil becomes sour by the accumulation of acids from the dead vegetation, and the organic material, instead of being turned to nitrates, forms peat. The addition of lime to such soils corrects the acidity, but draining is necessary to promote the activities of the bacteria. The fertility of the soil is then effected exactly as it would be by the addition of more nitrogen.

Three sets of bacteria are concerned in the work of nitrification. The first group simply turns the nitrogenous parts of the humus to ammonia, a process which is often called *ammonification.* In this process the animal and vegetable matter in the soil serves as food for the bacteria which may be said to digest it, excreting ferments, or enzymes, for the purpose. Considerable carbon dioxide is also liberated in this process, and this serves to further weather the soil particles. The ammonia produced by the bacteria combines with soil water to form ammonium hydroxide (NH_4OH), and at this point a new group of bacteria, known as *Nitrosococcus*, turns

the ammonium hydroxide into nitrous acid and hydrogen by the addition of an atom of oxygen ($NH_4OH + O = HNO_2 + H_4$). The nitrous acid combining with various minerals in the soil form nitrites, and a third set of bacteria, of the genus *Nitrobacter*, now adds another atom of oxygen to this compound, forming the nitrates used by plants. Although nitrites and nitrates differ principally in the possession of one more atom of oxygen by the latter, plants seem able to use only the nitrates. *Nitrobacter*, so far as known, is the only bacterium that can turn nitrites into nitrates.

Nitrogen fixation. Certain plants known as legumes, of which the bean, pea, clover, and alfalfa are examples, have the power to fix atmospheric nitrogen, or, rather, they have set up a partnership with bacteria which are able to do so. In this partnership the bacteria (*Pseudomonas radicicola*), in return for the carbohydrates which they need, give to the legumes the nitrogen which they are able to take from the air. Such a partnership as this is called *symbiosis*, and the partners are known as *symbionts*. Certain algæ in the soil seem also to have entered into symbiotic relations with bacteria for the purpose of getting nitrogen. By carefully digging up any legume and washing off the soil clinging to the roots the nodules which the bacteria inhabit are easily seen. Another bacterium, *Azotobacter chroococcum*, appears to be able to fix atmospheric nitrogen by itself, oxidizing carbohydrates in the soil in the process. The fact that lands allowed to lie without cultivation, or *fallow*, for a time, increase in nitrogen content is attributed to the presence of this and other bacteria. The

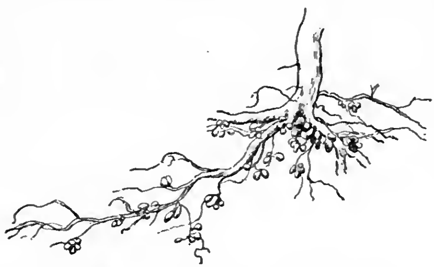

FIG. 85. Nodules on the roots of a legume

fixing of nitrogen, however, cannot go on without lime. Owing to the power of their bacterial symbiont to fix nitrogen from the air, legumes are able to thrive in soils too poor in nitrogen to support other crops. In sandy regions, where the loose and open soil permits the loss of nitrates almost as fast as formed, legumes are usually abundant.

Mycorrhizas. In a considerable number of plants, among which are various trees and shrubs, the older parts of the roots are inhabited by fungi known as *mycorrhizas*, which enter into symbiosis with them. Such associations are common, or possibly the rule, among woody plants, but are especially abundant in the heath family, to which the rhododendron, cranberry, and blueberry belong. The mycorrhizas extend out into the soil and function like root hairs. They appear to have the power to fix nitrogen from the humus in the soil and absorb sugars derived from fallen leaves by other soil bacteria. Certain flowering plants, like the Indian pipe and the pinesap, which lack chlorophyll, absorb all their food in this way. Mycorrhizas are also frequently associated with plants that transpire slowly; otherwise these plants would find difficulty in getting sufficient food.

FIG. 86. The snow plant (*Sarcodes sanguinea*)

A saprophytic heathwort (allied to the Indian pipe, *Monotropa uniflora*) from the Pacific Coast region

Soil inoculation. In many soils it is difficult to get a good crop of legumes because the necessary bacteria for symbiosis do not occur there. Experiments seem to show that each species of legume, if it does not have its own special bacterial species, has at least a special form with which it is associated,

and when this is missing it cannot thrive. In some cases, however, the form of bacteria associated with one species may be gradually induced to form partnerships with another. When the necessary bacteria are lacking, the soil may be inoculated by a few bushels of soil brought from another field in which the desired crop grows well. This is scattered over the field at the time of planting exactly as one would scatter seeds. In a few instances the bacteria of two species seem to be interchangeable. Fields in which red clover or alfalfa will not grow because their bacterium is absent, may be made to produce these crops by inoculating with soil brought from the nearest patch of wild sweet clover. In the same way the bacterial symbiont of cowpeas may be supplied from soils in which the wild partridge pea occurs. Several attempts, more or less successful, have been made by the national government and by private parties to send out dormant cultures of bacteria for use with certain crops. The seeds of the crop desired are inoculated with the bacteria before sowing. In the case of many cultivated species of legumes, and possibly all wild ones, the bacteria with which they form associations are transported into new soils by clinging to the seeds.

Denitrifying bacteria. Along with the bacteria in the soil which turn nitrogenous substances to nitrates are found other bacteria which reverse the process, and, by extracting the oxygen from nitrates, set free the nitrogen. This process goes on most rapidly in soils which are not properly aërated. Stable manure, left in piles, loses much nitrogen in this way. When plenty of oxygen is present the bacteria do not attack the nitrates.

Harmful organisms in the soil. As we have seen, the living elements of the soil are quite as important as its mineral constituents. In addition to the nitrifying and denitrifying bacteria and the nitrogen-fixing bacteria, there are many yeasts, algæ, fungi, germs of plant diseases, and hosts of

protozoa. The protozoa are one-celled animals that feed upon the helpful bacteria, often to such an extent as to effect the fertility of the soil. These may be killed or reduced in numbers by burning or boiling the soil, or by treating it with disinfectants. Such treatment does not appear to materially harm the bacteria. The increase in fertility in soils burned over is attributed to the fact that the burning killed the protozoa. Florists usually bake the soil in which young seeds are to be sown, or they may pour boiling water over it, and in this way get rid of the harmful organisms in it.

Limiting factors in plant growth. The production of the maximum crop is thus seen to depend on many things besides a sufficient amount of the necessary chemical elements in the soil. The temperature may be too high or too low, there may be too little sunshine at some critical period of plant growth, or the soil itself may contain too much or too little moisture. Any unfavorable condition at once becomes the limiting factor in plant growth, and changing this condition frequently results in doubling or trebling the crop. In the West water is often the limiting factor, but under irrigation or in regions of sufficient rainfall the lack of some mineral constituent of the soil is likely to prevent the maximum yield. The presence of insects or plant diseases may also affect the crop, and thus the limiting factor may even change from year to year, with favorable or unfavorable seasons. By supplying the soil with sufficient fertilizers and regulating by irrigation, drainage, and cultivation the amount of moisture in it, the farmer renders favorable such conditions as can be controlled, which fortunately are among the most important. The photographs on pages 102 and 103 illustrate very clearly the change that may result from adding a single chemical element to the soil. Here the application of a fertilizer containing phosphorus had the effect of immediately adding nearly twelve bushels an acre to the crop.

PRACTICAL EXERCISES

1. Make an expedition to the fields and woods for evidences of "fairy rings."

2. In the experiment garden make a test of the soil as directed on page 104.

3. Make a collection of all of the commercial fertilizers. Label.

4. Make a list of all the legumes, cultivated or wild, that can be found in the school garden.

5. Make a list of the wild legumes of the region.

6. Make up an extract of rich soil by soaking it in water. Put a drop of the turbid water on a slide and examine with the high power of the microscope for the bacteria.

7. Dig up clover or other legumes and look for the nodules on their roots.

8. Crush a nodule and examine it under the microscope.

9. What is the limiting factor of plant growth in your region?

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123. Red Clover Seed.
144. Rotation of Crops.
192. Barnyard Manure.
237. Lime and Clover.
245. Renovation of Worn-out Soils.
278. Leguminous Crops for Green Manuring.

Bureau of Plant Industry

71. Soil Inoculation for Legumes.
173. Seasonal Nitrification as influenced by Crops and Tillage.

CHAPTER VIII

THE PLANT IN RELATION TO TEMPERATURE, LIGHT, AND MOISTURE

Growth temperature. The range of temperature that vegetation in the aggregate can endure is remarkable. Seeds in the dormant condition have been exposed to the temperature of liquid air, many degrees below zero, without impairing their vitality; and, on the other hand, some algæ can exist in hot springs where the temperature of the water reaches nearly to the boiling point. No single species, however, can endure anything like this range of temperature. Ordinary plants are balanced midway between two rather close extremes of heat and cold, growing well so long as neither is too closely approached, going into a dormant condition when brought nearer, and dying when either extreme is reached. Differences in temperature are among the principal factors controlling the distribution of plants. Elevated country and mountain ranges act as barriers to the spread of tropical plants, because the upper regions are cold, and a stretch of warm lowland may prevent the migration of alpine vegetation from one summit to another; in fact, there is scarcely a species that is not sharply limited in some part of its range by temperature.

A temperature of 122° above zero is fatal to most land plants in the growing condition, and aquatics usually perish at somewhat lower temperatures. Plants and plant parts generally can endure the greatest amounts of heat and cold when they contain the least water. In seeds, developed by the plants for carrying them over unfavorable seasons, the protoplasm is brought to the resting and more resistant condition by the

exclusion of most of the moisture. Some hardy arctic plants, however, can be frozen and thawed several times a day during the growing season without being injured.

The plants of a given region have their own peculiarities in the matter of the temperature at which growth processes begin. In the arctics certain seaweeds thrive in water that seldom rises above 32°, and are easily killed by temperatures a few degrees higher. Most plants of the temperate zone will begin to grow at about 41° above zero, and some, such as oats, wheat, rye, and peas, can make some growth when the temperature is just above the freezing point; but the best temperature for germination is between 60° and 70°, and many species, even in the colder parts of the world, will not start to grow until such temperatures are reached. Up to a certain point heat seems to stimulate growth processes just as it does chemical reactions. In the tropics the temperature at which seeds germinate is usually ten or twelve degrees higher than that required for more northern plants, the most desirable being between 70° and 80°. The seeds of many tropical species, when planted in our hothouses, must be given a temperature above 90° to get the best results. These facts explain why some seeds are planted earlier than others. Peas and spinach are cool-weather plants and may be planted as soon as the ground can be worked in spring; indeed, unless the season is fairly cool these crops do not do well. Corn and tomatoes, on the other hand, which came originally from the tropics, must wait until both the soil and air are thoroughly warmed.

Hardy and tender plants. As regards the sensitiveness of the plants to cold, gardeners are accustomed to group them as hardy, half-hardy, and tender species. *Hardy* plants are those that endure the winter season unharmed. The perennial plants of any region are necessarily hardy plants. *Half-hardy* plants are those that need artificial protection during the winter, though in mild seasons they may survive without this.

Tender plants are those that die as soon as frost comes. These are general terms, however, and indicate relative conditions only, since a plant that is perfectly hardy in one region may be only half hardy or even tender in a colder one. On the other hand, the trees that are deciduous in cold regions may become evergreen when removed to warm regions. Violets, which flower for only a few weeks in spring in the Northern states, may bloom throughout the autumn, winter, and spring near the Gulf.

Cardinal points. As has been indicated, there are three important temperature points for every species of plant: the *minimum*, or lowest point at which growth processes can proceed; the *maximum*, or highest point at which growth is possible; and the *optimum*, or most favorable temperature. These points are called *cardinal points*, or the *upper*, *middle*, and *lower zeros*. They are not the same for all plants, and in general are higher for tropical plants than for those of temperate regions. Each species may also have a different maximum, minimum, and optimum for its vegetative and reproductive processes. In such cases the cardinal points for growth are usually higher than those for reproduction. The large number of species that flower in early spring, often before the leaves have appeared, are instances of this fact.

Acclimatization. Some plants of tropical regions can be induced to grow much farther north than they occur in nature, and the same is true with respect to northern plants in more southern regions. The adaptation of plants to such conditions is called *acclimatization*. Complete acclimatization is possible only with plants that are able to make new adjustments of their cardinal points, raising or lowering them to fit the new conditions. Sometimes the vegetative point may be thus changed, but not that for reproduction, in which case the plant may produce plenty of stems and leaves, but no flowers or fruits. Our most persistent and successful weeds are largely

so because of the facility with which they are able to make new adjustments of their cardinal points.

Frost. The air always contains some moisture, and the warmer the air the more it can contain. When it contains all that it will hold at a given temperature, it is said to be *saturated.* If the temperature of moist air be lowered beyond the saturation point, some of the moisture has to be dropped. If this occurs in the air, the dropped moisture is called *rain* or *fog;* if deposited on the earth, it is *dew* or *frost.* The point at which the water begins to condense out of the air is called the *dew point.* Frost differs from dew only in that it is deposited at temperatures below the freezing point of water. There is always danger of frost when the weather report predicts temperatures eight or ten degrees above freezing, since in any given locality the temperature may fall a few degrees below that predicted. A still clear night favors the formation of frost by promoting the cooling of the earth and air by radiation. When the sky is cloudy, the clouds, like a blanket, keep in the heat. A fog at night, or much smoke or dust in the air, protects in the same way. A windy night may also protect from frost by moving the cold air about and keeping it from settling down in any one place.

Locality and frost. Danger from frost is not confined to northern latitudes. In any region where the temperature goes below the freezing point there is danger from late spring and early autumn frosts. The location, however, often has much to do with immunity from frost. In the vicinity of large bodies of water frosts are often long delayed in autumn because, as the temperature lowers, the water gives off the heat absorbed during the summer and thus keeps the surrounding air warm. In rooms or cellars where the temperature might fall below the freezing point, this may be prevented by exposing therein tubs of water which will give off heat in the same way. Cold air is heavier than warm air and tends to settle in the hollows

and displace the warm air there. In consequence frost often visits the bottom lands long before it touches the hilltops, because the latter are nightly bathed in the warm air crowded up from below. For this reason farmers usually plant the late crops of buckwheat on the hillsides. In certain valleys there is a zone part way up the slope, called the *verdant zone* or *thermal belt*, in which late spring and early autumn frosts are almost unknown. This zone is due to the movement of the warm air out of the valley at night. Other inclosed valleys drained by a stream may be nearly exempt from frost because the cold air flows away over the stream. This distribution of temperature has a curious effect upon the distribution of plants. Northern plants are usually found farthest south in the valleys, and southern plants farthest north on the hillsides, exactly the opposite of what at first glance one would assume to be the natural occurrence.

How cold kills plants. Some tropical plants are so sensitive to cold that they may be killed by exposure to temperatures several degrees above the freezing point, but usually plants are killed by the freezing of the protoplasm or the sap within the cells. Freezing of the cell sap takes place at a temperature somewhat lower than 32°, since water containing dissolved substances requires a greater degree of cold to congeal it than does pure water. Often it is not the mere cold that kills plants, but rather the withdrawal of moisture from the cell by the formation of ice crystals in the intercellular spaces. In such cases the effects of cold are exactly the same as those of drying. Otherwise hardy plants are often killed in winter by the heaving due to the alternate freezing and thawing of the soil and the consequent breaking of the roots.

Other effects of cold. In plants that are not killed outright by the cold, the lowered temperature may injure the less resistant parts. Some plants, such as the catalpa, grape, raspberry, and sumac, continue to grow until stopped by the cold,

and the stems do not form strong buds at the tip. In these the buds and stems are usually killed back several inches annually. Flower buds that are formed in autumn are often killed by the cold, especially by a cold interval in late spring after they have started into growth. Flowers, of course, are sensitive to cold and may fail to set fruit even if the temperature does not fall to the freezing point. In severe winters the trunks of trees are often split open by the cold. Another effect of the cold is seen in the improvement in the flavor of certain vegetables such as salsify and parsnips.

How plants avoid the effects of cold. Most perennial plants have devised various ways of protecting their more delicate parts from the cold. A large number have developed the *geophilous*, or subterranean, habit, and at the approach of cold weather the parts above ground die and the life of the plant retreats to the underground parts. Examples are seen in the species that produce bulbs, corms, tubers, rhizomes, and similar structures. The same arrangement also protects from drought. Bulbous plants are always plentiful in dry regions. Plants above ground have other means of protection. The trees protect the living cambium by a thick and nearly waterproof bark, and their buds are protected by scales, hairs, and varnish. Most of the broad-leaved trees drop their leaves to avoid transpiration, but the pines and their allies with needle-shaped leaves that do not transpire much are not obliged to do so. The twigs and stems of many plants have a dense coating of scales, epidermal hairs, or wax, as an additional protection. How effective epidermis and bark are in retaining moisture in the plant may be seen by comparing the behavior of a peeled apple or potato with that of one in its natural state. Herbs that retain their leaves adopt the rosette habit, and thus their leaves, close to the earth, are protected all winter by the dead vegetation and the snow. The majority of these devices, it may be noted, are not so much protections from the cold

as they are means of avoiding the injuries likely to be caused by sudden changes of temperature. On the other hand, the dark colors of bud scales readily absorb heat in sunshine and

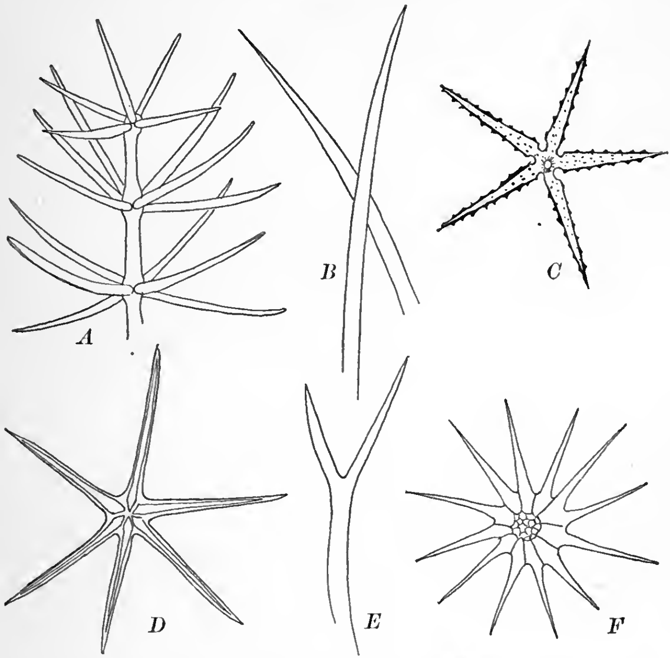

FIG. 87. Epidermal hairs and scales. (Much enlarged)

A, mullein; *B*, geranium; *C*, deutzia; *D*, hollyhock; *E*, dame's violet; *F*, shepherdia

may thus increase the temperature of the buds during the cool days of early spring.

Artificial protection from the cold. Snow is of such great value as a protection of plants in winter that it is frequently called "the poor man's manure." Winters in which there is little snow are very trying to plants because they are left unprotected and are thus easily heaved by the frost. Man often adds to the natural protection of plants by mulching, shading,

windbreaks, and cold frames. *Mulching* is simply adding to the cover of dead leaves with which the ground is naturally protected in winter. Any loose litter is good for this purpose. Straw, leaves, and stable manure are the materials most frequently used. In addition to protecting plants from being heaved by the cold, a mulch retards the thawing of the ground in spring and thus holds back early plants that might otherwise be injured by late frosts. *Windbreaks* are belts of trees, usually evergreens, planted on the windy side of gardens and fields to protect them from the high winds of winter and early spring. In nature the forest acts as a natural cover for a vast number of plants. *Cold frames* are frames of wood covered with glass or thin cloth, which are sometimes placed over plants. They are either sunk in the ground to the level of the soil, or are banked up with manure. On very cold nights they are covered with mats as an additional protection. Sprinkling plants with cold water may protect them from frost when the temperature does not go much below the freezing point. In orchard practice the blooming trees are often protected from late spring frosts by smudge fires, which give off great quantities of smoke that act like clouds in keeping the earth warm.

Treatment of frostbitten plants. Plants that have been frostbitten may often be saved by gradual thawing, especially in cases where the injury is due to a withdrawal of moisture from the cell. If possible, such plants should be removed at once to a cool cellar, sprinkled with water, and kept out of the direct rays of the sun for a few days. Out of doors the plants may be sprinkled with water and protected from the sunlight. Frostbitten plants and fruits should be handled as little as possible until thawed.

Effects of heat. The first noticeable effect of great heat upon the plant is the wilting due to increased evaporation. As the temperature rises, the plant is called upon for more and more moisture until a point is reached where the demand

is greater than the roots can supply, and the drooping of the foliage ensues. If this continues long enough, it may cause the death of the plant, though in bright sunshine a great many plants wilt during the hottest part of the day and revive as the temperature falls. The watery parts of plants, especially the fruit and young leaves, being less resistant to heat than the rest of the plant, are often destroyed by exposure to the hot sun. Evergreens and other plants are sometimes winterkilled, not so much by the cold as by a sudden spell of warm weather that calls upon stem and leaves for more moisture than they can spare at a time when the roots are only feebly absorbing.

Protection from heat. Since the direct rays of the sun are more harmful than the heated air, tender specimens may be protected in a measure by screens of thin cloth, paper, brush, or lath. Newly transplanted specimens are often sheltered by old newspapers or by a broad leaf, such as that of the burdock or rhubarb. In all such shading it is well to provide for a circulation of air under the cover. Plants in greenhouses and the like are usually shaded by covering the underside of the glass with whitewash. Evergreens and other plants that are not perfectly hardy will often best endure the winter if planted on the north side of buildings or in places where the direct sunshine may be avoided.

The plants themselves have various devices which protect them from the heat. The leaves of species exposed to the sun are frequently covered with a dense coat of hairs or scales which shade the tender cells. On a hot day the leaves of corn roll up and thus expose a smaller surface for evaporation. The prickly lettuce, the compass plant, and the eucalyptus turn the edges of their leaves to the sun, and many tropical species shed part or all of their leaves during the season of greatest heat. The acacias and many other plants of the pea family, with branched leaves, alter the position of their leaflets

to avoid the heat, while in various other plants the chloroplasts are able to change their position in the cell.

Need of light. Light is necessary for the existence of every independent plant, since the energy for food making is derived from this source. The general effect of light upon plants, however, is to inhibit growth, and chlorophyll itself, the very substance by means of which the chloroplasts turn sunlight into useful energy, is broken down in strong light. Bacteria soon die when exposed to direct sunlight, and many of the higher plants cannot live long under such conditions. These latter grow in forests, ravines, and other secluded places and are known as *shade plants.* Ferns and many of the plants that bloom in early spring are shade plants. Many of our forest trees are essentially shade plants when young. Absence of sufficient light, however, is quite as bad as too much. In insufficient light the formation of wood cells entirely ceases. As in the case of temperature, the plant is balanced between two harmful extremes.

Effects of lack of light. Sun-loving plants grown in deep shade are deficient in chlorophyll, and have small leaves and weak stems which are greatly elongated, or "drawn." The flowers are also paler and the fruit scanty and lacking in flavor. Aromatic plants have their aromatic properties lessened when grown in shade. Plants may receive too little light by being planted so closely together that they shade one another, or where a subsequent growth of weeds springs up and overshadows them. Fruit trees and flowering plants, generally, may fail to form flower buds unless pruned sufficiently to let the light into the mass of foliage. A large number of woody plants have the faculty of self-pruning. This is regarded as a response to insufficient light. The cottonwood is one of the best-known trees with this habit. In winter the earth beneath old trees is thickly strewn with twigs a foot or more long, cut off by the tree as smoothly as the leaves are.

Blanching. Plant parts produced in darkness are paler and tenderer than when grown in the light, and this fact gives reason for the process known as *blanching*. Plants may be blanched by heaping up the soil about them, or by covering them with boards, tiles, or anything else that will exclude light. Celery and sea kale are always blanched for the table in this way, and asparagus often is. Endive is blanched by tying the outer leaves over the center a few weeks before using, and by the same method the heads of cauliflower are protected from the light and kept white.

Photograph by the University of Illinois

FIG. 88. Cauliflower plant

The leaves are tied above to blanch the center

Protection from light. Light and heat are so closely allied that what will protect from one will usually protect from the other. The *lath house*, built of common lath or of wider strips separated from one another by sufficient space to admit some of the light, is often used for growing shade plants, slow-growing seedlings, and similar specimens. In addition to this protection from light and the attendant heat, the lath house retains the moisture in the air. Artificial shading by means of thin cloth or lath screens is frequently employed in the cultivation of tobacco, coffee, pineapples, and ginseng. In summer radishes and lettuce come to much greater perfection when grown in the shade.

Effects of overwatering. Although plants need much moisture, they may very easily have too much, which results in various abnormal conditions. Tomatoes, cabbage, melons, plums, and other fruits are liable to crack from this cause, when heavy rains follow a drought. Anything that will cause a reduction in the water supply may act as a remedy. In the case of cabbage, pulling on the stem so as to break some of the roots may prevent the heads from bursting. House plants are frequently overwatered. Few plants can long keep up the struggle if left standing in a jardinière containing an inch or more of water.

Time to water. Air in the soil is a necessity. A saturated soil is as harmful as one that is too dry. About 50 or 60 per cent of the moisture a soil can hold is about the amount desirable. When watering plants it is better to give the ground a good soaking at considerable intervals than to give it more frequent applications of smaller amounts. Light watering makes plants shallow rooted and more susceptible in times of drought. A few plants, such as the geranium, petunia, and tomato, possess glandular hairs which have the faculty of absorbing moisture from the air or from dew. This accounts for their ability to thrive in places too dry for ordinary plants. The so-called "Spanish moss" of the Southern states, which is really a relative of the pineapple, absorbs all its moisture through its leaves.

Effects of lack of water. Plants grown without an adequate supply of water are inclined to be short and stunted, but the lack of moisture favors the development of flower buds and causes the wood to ripen. A large number of our spring flowering plants form their flower buds during the heat and drought of summer, and florists allow their plants to become pot-bound when flowers are desired, since this prevents the absorption of much water and food materials. Removing part of the root system may have the same effect.

Water and plant forms. Although the character of the soil determines in great measure the kind of plants that will thrive in it, and temperature may have much to do in determining their distribution, water is of still greater importance, since it affects both the form and structure of vegetation. The plants of the world may be separated into three ecological groups, known as xerophytes, hydrophytes, and mesophytes, according to the amount of water to which they are adjusted. The *xerophytes*, or drought plants, can thrive with a very limited supply of moisture. They inhabit deserts and other dry localities and are characterized by many adaptations for conserving moisture, such as condensed stems, reduced leaf surface, thick epidermis, an extensive root system, and various tissues for water storage. Many xerophytes are leafless and the stems perform the work of photosynthesis, others have leaves for a part of the year but drop them when seasons of drought occur. In the species which retain their leaves, the latter are usually covered with hairs, scales, or bloom. Xerophytes often have their stems underground in the form of rootstocks, bulbs, and corms, and the production of thorns and spines by woody species is common. The cactus, yucca, and houseleek are xerophytes. All xerophytes do not live in deserts, however. A rocky ledge or a sand dune, though located in a region of abundant rainfall, may hold so little moisture that the plants that grow upon them are exposed to desert conditions and may have all the characteristics of drought plants. The lichens which grow upon

FIG. 89. *Yucca glauca*, a xerophyte of the Western plains

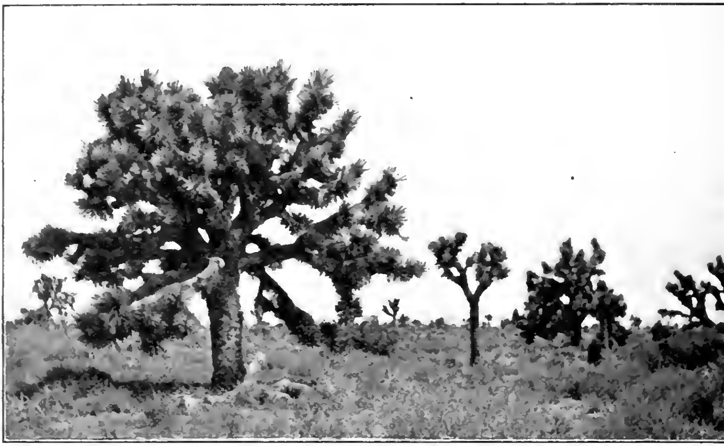

FIG. 90. Tree yuccas, xerophytic plants of the Mohave Desert

the trunks of trees, rocks, and in similar places are examples of such plants. *Hydrophytes* are water plants and thrive only in regions of abundant rainfall. The water lily, pickerel weed, ditch moss, and pondweed are good illustrations. They are

FIG. 91. The American lotus (*Nelumbo*), a hydrophyte

characterized by weak stems, thin epidermis, few roots, little conducting tissue, and large air spaces within stems and leaves, all of which are necessary to fit them to their environment. The leaves under water are usually narrow or much branched, though those exposed to the air may be as large as, or larger than, in other plants. Along with the true hydrophytes are often found other plants that are xerophytic in structure, though growing in water. These are sometimes known as

FIG. 92. A group of hydrophytes, showing the zonation that often occurs

In the water, spatter-dock (*Nuphar*) and algæ; on the muddy shore, a belt of cattails; in the background, cottonwoods and willows

xerophytic hydrophytes. They are, for the most part, plants which absorb so slowly that they have been obliged to adopt the structure of xerophytes in order to retain what moisture they absorb. The scouring rush illustrates plants of this type. The *mesophytes* occupy the middle ground between the xerophytes and hydrophytes. They are the common plants of our woods and fields, and though of far more economic importance than either of the other classes, they are of much less botanical interest.

PRACTICAL EXERCISES

1. Visit the nearest hothouse and note the character of the tropical perennials that require great heat for growth.

2. Ascertain from the nearest weather observer, or from farmers who have kept records, the average date of the last killing frost in spring and the earliest killing frost in autumn. How many days of growing weather does this give you? Find the date of the latest recorded spring frost and the date of the earliest autumn frost. How many days from frost to frost? How does this compare with the average?

3. Into a bright tin cup, nearly filled with water, drop pieces of ice one by one, stirring the mixture with a thermometer. When moisture begins to appear on the outside of the tin cup, the thermometer will register the dew point. Where is the dew point higher, in the schoolroom or in a sheltered place outside? In which place does the air hold the more moisture?

4. Find a place where a board, paper, or other object has been lying on the grass for a few days. Remove it and account for the appearance of the grass underneath.

5. Examine potatoes or other plants that have grown in a cellar or other dark place. Explain the appearance of the plants.

6. Make lath screens for use in the garden later, or draw plans to scale for a lath house to be constructed in the garden for growing the shade plants.

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CHAPTER IX

GARDEN MAKING

Location of the garden. The ideal location for a garden is in a well-drained spot, open to the south and east, and protected at least on the north by a belt of evergreen trees, a high wall, or a tight board fence, but any place is suitable if it receives the direct rays of the sun for at least half of the

FIG. 93. A class at work on a city lot, Joliet, Illinois

day. Land sloping toward the north should be avoided and so should a locality where there is much smoke. In the majority of cases, however, it is not possible to select a new site for the garden, and one's efforts must be directed toward bettering the one he already possesses. The nearer it can be

made to approach ideal conditions the better. If the garden is to contain fruit trees, these should be placed along the north line or otherwise disposed so that they will not shade the growing crops.

Preparing the soil. The best soil is a deep and moderately light loam, but here, again, one must make the best of his situation. Large stones should be removed, but small ones may remain. Gravelly soils are early soils because during the day the stones absorb much heat which they radiate at night. If the soil is a stiff clay, it may be lightened by the addition of sand, coal ashes, lime, stable manure, dead leaves, and other litter. Sandy soils may be improved by digging into them anything that will add humus, and any soil will be benefited by the application of well-rotted manure. The soil should be made mellow by plowing or deep spading, all lumps should be broken up with the rake or hoe, and the surface finally leveled with a rake. The care with which the seed bed is made will be reflected in the crops. It is not economy to plant until the soil has been properly prepared.

The garden plan. Before planting, a plan of the garden drawn to scale should be made. In this plan all paths and permanent crops and the area devoted to each vegetable should be indicated. By this means one can discover in advance exactly how many plants he will have room for, and can plant any part of his space without encroaching upon that reserved for other things. Permanent plants, such as raspberries, currants, asparagus, and rhubarb, should be restricted to the borders where they will not interfere with the cultivation of the other crops year after year. Many paths should be avoided, but those that are maintained should enable one to reach all parts of the garden expeditiously and should be wide enough to permit of being traversed with a wheelbarrow. It is no longer the custom to plant the smaller vegetables in narrow beds. They should be planted in rows,

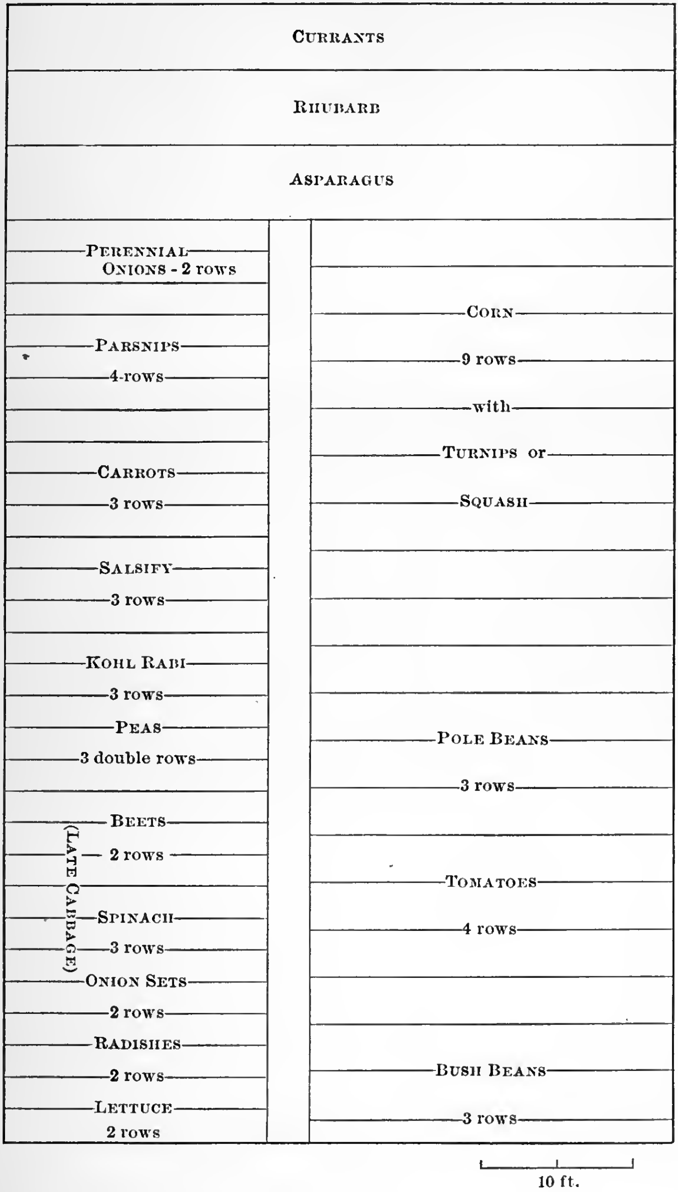

FIG. 94. Plan of a garden for a city lot

the longer the better, to permit of the ground being worked more easily. Care must be taken, however, to so arrange the planting with reference to the points of the compass that tall growing plants are not placed where they will shade lower ones. In general, it is well to place nearest the house the salad plants and others that are gathered frequently, leaving the field crops, like potatoes and cabbage, to occupy more distant spots.

How to plant. A few plants, such as corn, cucumbers, tomatoes, and pole beans, are planted in hills, but all that can

Fig. 95. Gardening at the Flower Technical High School for Girls, Chicago

be grown in drills or rows are so planted to facilitate cultivation. Care should be taken to have the rows straight and far enough apart to avoid crowding. The proper distances may be learned by consulting the planting table on page 145. To facilitate measurements in the garden, the handle of hoe or rake should be laid off in six-inch sections. The marks can be scratched in the wood with any sharp-pointed instrument and inked, if desired. Straight rows may be secured by means of a garden line, such as masons use, stretched between two stakes.

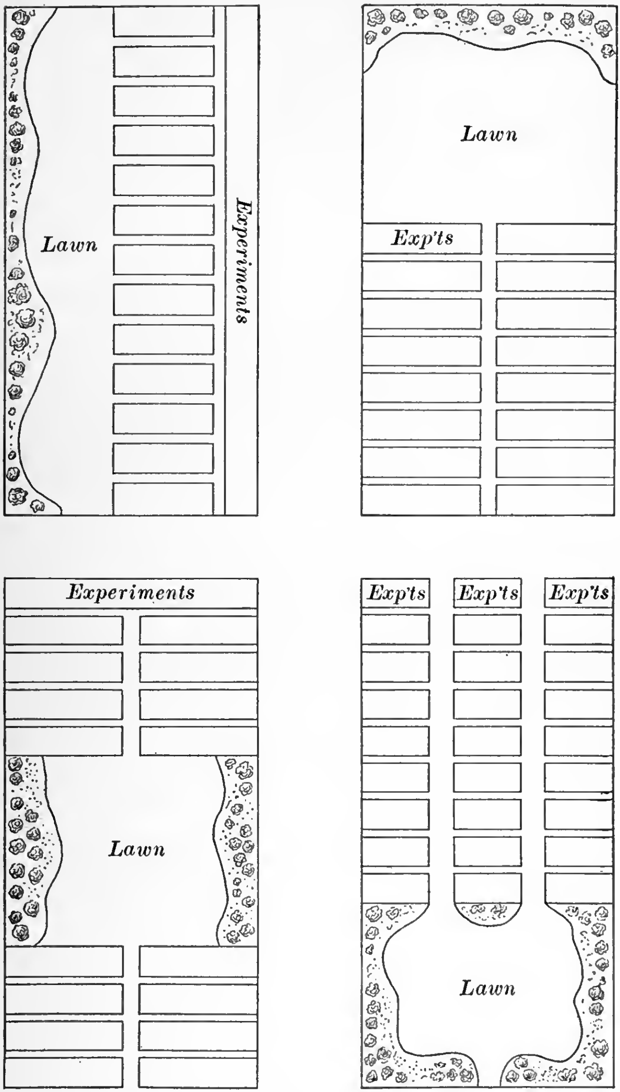

FIG. 96. Four plans for school gardens on vacant lots

When not in use it should be kept with the seeds where it will be ready when more planting is to be done. Seeds must not be planted too deep. In general they should be planted three or four times as deep as their diameters. Seeds whose cotyledons do not rise above the soil may be planted deeper than those whose cotyledons do, and large seeds may be planted deeper than smaller ones. Very small seeds may be simply scattered on the surface and pressed into the soil with a hoe or a piece of board. When sown in light, well-drained soil, the seeds may have the earth firmed over them to induce capillarity, but in wet or heavy soils this should be omitted, else it may be so compacted that delicate plants cannot push through it and the air necessary for germination be excluded. Darkness favors the germination of most seeds, and for this reason, as well as to prevent the drying out or puddling of the surface layer of soil, it is well to mulch newly planted seeds with a light covering of loose straw or lawn clippings through which the young plants easily push their way. Covering the planted seeds with paper or cloth serves the same purpose, but in such cases the cover should be removed as soon as the young plants appear.

When to plant. The seeds of the hardier plants may be sown as soon as the ground can be worked in spring, or they may even be sown in the autumn and allowed to rest in the soil through the winter. This is the way all the wild species are planted. Other seeds must not be planted until the soil is thoroughly warmed. Several garden plants thrive only in the cool moist days of early spring, and do not grow well if planted later. This is especially true of spinach, cress, radishes, lettuce, and the like. In hot dry weather these plants soon "run to seed." Among the vegetables that are usually planted early are beets, cabbage, cress, lettuce, onions, peas, radishes, salsify, and spinach. These are either cool-season or long-season plants that are not injured by light frosts. Warm-season

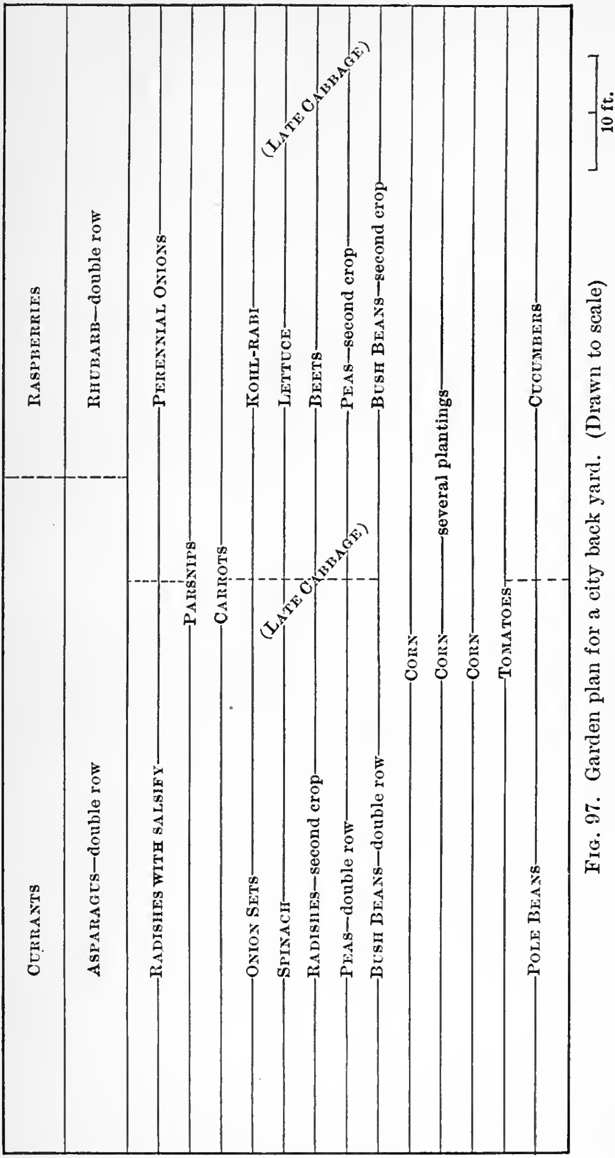

Fig. 97. Garden plan for a city back yard. (Drawn to scale)

plants, such as corn, cucumbers, okra, peppers, and tomatoes, must not be planted outdoors until all danger from frost is past.

Autumn seed bed. The seeds of all hardy plants may be sown in autumn and will lie in the earth unharmed until spring. Some will even grow in autumn and go through the cold season as seedlings. Autumn seed sowing has the advantage that it may be done at a time when other work is not crowding, as in spring, and the stay in the soil over winter will aid in softening the seed coats of many species. In autumn, also, fruiting plants are everywhere and seeds are abundant. It is much easier to carry home a dozen plants as seeds than to transport the same number when they have grown for a year or more. The autumn seed bed should be made in a sheltered situation, and when cold weather has come, it should be mulched with some good litter that is free from weed seeds.

Germination. The promptness with which the young plants appear above the soil depends upon the kind of seed planted, the temperature of the soil, the amount of moisture present, and various other things. In cold, wet soils seeds of most sorts are slow to germinate, if they grow at all, though a few will sprout at temperatures but slightly above freezing. Increasing the temperature, however, hastens germination, and in dry weather soaking the seeds before planting has the same effect. Hardy plants usually do best at temperatures of from 50° to 70°, tender plants from 60° to 80°, and tropical plants from 75° to 95°. In favorable weather from three days to two weeks may elapse between planting and the appearance of the seedlings. Seeds of canna, lotus, honey locust, and some others have testas so hard that they delay germination by excluding moisture and air, but they grow readily when a hole is filed through the testa before planting. Boiling water is sometimes poured over such seeds to hasten germination. The

seeds of nut trees and our stone fruits have testas so thick that they may remain in the earth for a year or more before growing. In such cases germination may be hastened by cracking the shells or by *stratifying* the seeds. The latter process consists in placing the seeds in layers in boxes of moist sand or moss and keeping them moist during the winter. The seeds may be kept in a cool cellar or buried a foot or more deep in a well-drained spot. Seeds may fail to grow for various reasons. They may be too old, may have been frozen before being thoroughly dried, their testas may exclude oxygen or moisture, or they may have been immature when gathered. The seeds of many plants will not grow the same season they are produced, even if surrounded by the most favorable circumstances. The length of time that good seeds retain their vitality depends somewhat upon the species. A few seeds must be planted almost as soon as ripe if they are to grow at all, while others will remain alive for from two to twenty years. In general, starchy seeds retain

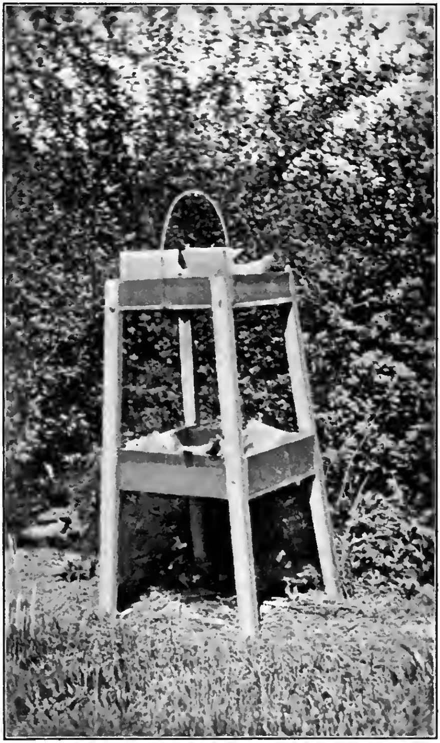

Fig. 98. A handy receptacle for seeds, labels, and other small things

This is easily made and can be carried into the garden whenever planting is to be done

their vitality longer than oily ones. There is no truth, however, in the idea that seeds thousands of years old, found in the pyramids or dug out of Indian graves, will grow. Weed seeds are especially persistent, but few of them can grow after twenty years. In some seeds the age seems to affect the crop, fresh seeds producing more vigorous plants with a tendency to put forth leaves and stems only, while older ones are likely to be more fruitful. Growers of melons prefer seeds several years old for this reason.

Seed testing. When a crop is planted upon which much depends, or when for any reason there is doubt about the seeds being good, it is customary to test them before planting. A

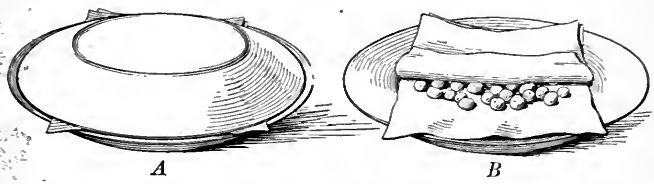

Fig. 99. A seed tester, consisting of two soup plates, some sand, and a piece of cloth

serviceable seed tester may be made of a dinner plate, a sheet of glass, and two pieces of rather thick cloth cut to fit the plate. The cloths are dipped in water, the excess moisture wrung out, and the seeds to be germinated placed between them. The cloths are placed on the plate and covered with the glass or another plate to keep in the moisture, and the apparatus set away in a warm place. From time to time the seeds are examined and those which have germinated removed. By this means one may very quickly discover what proportion of a given lot of seeds is viable. Wet sand may be used in place of the cloth in the seed tester, if desired.

Double cropping. Different crops vary greatly in the time taken to mature. Long-season crops, such as salsify and parsnips, are planted early in spring, occupy the ground until frost,

and are often left in the soil over winter. On the other hand, lettuce, radishes, and the like take but a few weeks to mature, and if such crops are planted together in one part of the garden, two and three separate crops may be grown on the same soil in one season. Among the plants most useful for second crops are beans, cress, celery, cabbages, kohl-rabi, lettuce, mustard, radishes, spinach, and turnips. Celery and cabbages used as late crops are started elsewhere and transplanted; the others are grown from seeds planted where they are to remain. Another method of getting two crops from the same soil, often practiced with long-season crops, is to plant together two crops, each of which has different requirements as to light, shade, etc. Pumpkins, turnips, and squashes are often planted with corn, and clover with grain crops. Radishes may be planted with salsify, beets, and other slow-growing crops, and help to mark the rows until the other plants have developed. Radishes and lettuce may also be planted between the hills in melon patches, where they will mature before the space is needed by the chief crop.

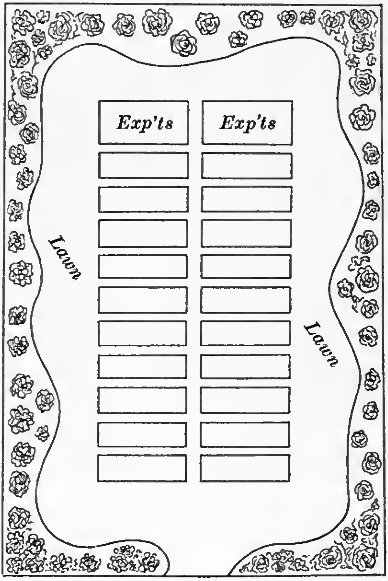

FIG. 100. A garden plan which may be used for a school garden or for the home lot

Transplanting. Almost any plant can be transplanted, but some endure such treatment better than others. Plants with strong taproots are more difficult to transplant. In general,

when directions on a seed packet say the seeds should be sown where the plants are wanted, transplanting should not be attempted. There are several advantages, however, to be gained by transplanting. Earlier crops may be produced by starting plants in the house before they can grow out of doors, and transplanting them to the garden when the weather has moderated. Plants that require a long season to come to maturity may also be induced to fruit earlier by this means. By starting plants in this way they may be set in the place of those that mature early and a second crop thus secured, or they may be used to fill up gaps in the plantings caused by the depredations of insects, plant diseases, or the failure of the seeds to grow. Warm-season plants are usually long-season plants also, and several of these, such as eggplants, peppers, and tomatoes, are always transplanted, thus securing earlier and more abundant crops. Other plants that are able to mature from seed planted in the open ground are usually treated in this way, especially cabbage, cauliflower, and celery. Beets, chard, lettuce, and onions are occasionally transplanted.

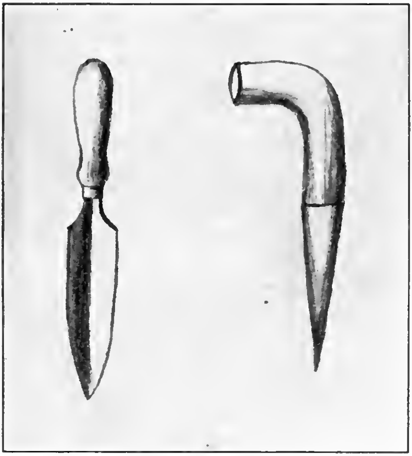

FIG. 101. A transplanting trowel and a dibber

A trowel of this kind is often used as a dibber

Transplanting should be done on cool or cloudy days and preferably in the late afternoon. Young plants may be transplanted as soon as they have developed their second or third leaves. Moving very young plants in this way is called

pricking out. The plants should be taken up with as many of the roots as possible, and should not be allowed to become dry by exposure to the sun and air. The holes in which they are planted may be made with a pointed instrument of wood or metal called a *dibber*. After the plants are placed in the holes the dibber is again thrust into the ground an inch or more from them and used to crowd the soil against them, thus making it firm. If the weather is very dry, the plants should be watered after setting, and protected from the wind and the direct rays of the sun until again established. Excessive transpiration may be reduced or avoided by removing some of the leaves or by cutting off part of each leaf. The latter operation is called *shearing*. Some growers are in the habit of allowing cabbage and tomato plants to wilt before resetting, with the idea that by so doing the plants will develop new roots instead of endeavoring to revive the old ones. These species are quite tenacious of life and survive much abuse. Frequently cabbage plants for transplanting are simply pulled up from the seed bed.

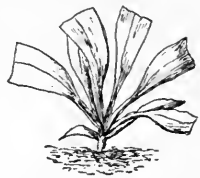

Fig. 102. A sheared plant

Inducing plants to fruit. It is natural that all mature perennial plants should flower and fruit annually, but it is a well-known fact that many do not do so. Fruiting is a very exhausting process. Annuals are killed outright by it, while in perennials a heavy crop of fruit may so depress the vitality of the plant as to make it impossible for it to bear at all the following season. When a plant sets more fruits than it should bear, some of them should be removed. On the other hand, in all plants in which great development of the vegetative parts is desired, it is customary to remove all the flowering shoots and fruits as soon as they appear. Thus we pick off the berries of asparagus and pinch out the flower stalks of rhubarb. Annuals may be made to take on a perennial character by

removing the flower buds as fast as they form. If one desires flowers and fruit, however, all efforts should be bent toward aiding the plant to store up reserve food, since the more food it has, the likelier it is to bloom. Fruiting is really a device of the plant for self-preservation, and whatever threatens the growth processes may serve to bring it about. A plant injured by lightning or defoliated by insects is likely to spring into bloom again even in autumn. Pinching back the tips, removing some of the roots, withholding water, or planting in sterile soil will usually induce the plant to fruit. Certain varieties of strawberries, pears, apples, plums, and other plants are often infertile when pollinated with pollen from their own flowers. Even when planted in groups they may produce abundant bloom but set little fruit. The remedy here is to plant among them other varieties with effective pollen. In a few other forms the pistils and stamens are produced on separate individuals, and no fruits can be produced, therefore, if the pollen-bearing plant is absent. Still other plants are adapted to cross-pollination by insects, and though the pollen-bearing plant or flower may be present, they set no fruits if the necessary insect fails to visit them. In growing melons, cucumbers, tomatoes, and the like in the hothouse, in winter, pollination must be performed by hand. Morning is the best time for this work. A soft camel's-hair brush, to which the pollen adheres, may be used for the transfer of the pollen, or a stick of sealing wax which has been electrified by rubbing with a cloth may be used to pick up the pollen grains and drop them upon the stigmas of the flowers to be pollinated.

Thinning. When the young plants are well up, it will be necessary to thin them, if planted very thickly. Thinning should be done as early as the plants can be conveniently handled, so that the specimens left may have room to develop naturally. Plants that are not thinned become drawn and spindling and do not produce good crops. The distance apart

in the row depends somewhat upon the habit of the plant. Plants with long narrow leaves, like salsify or onion, may stand closer than those with broad, spreading leaves, like turnip and parsnip. The main consideration should be to see that one plant does not unduly shade another.

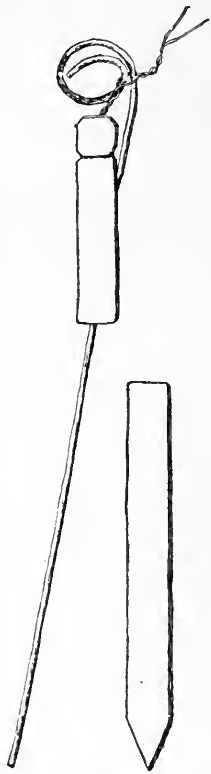

Fig. 103. Two forms of labels

The one on the right is the common garden or pot label; the other is a more permanent form for marking plants in the borders

Labels. All planted seeds should be properly labeled, partly as a matter of record and partly to indicate their whereabouts until the young plants are large enough to be seen. Older plants should also be labeled, especially if there are several varieties of the same species cultivated, or if other plants are grown that might be mistaken for them. The best label for temporary purposes is a wooden stake painted white. Such labels can be purchased from seedsmen at small cost. Those six inches long and about three quarters of an inch wide are about the right size, though smaller or larger ones may be had. On a label of this kind, words written with a pencil will be legible for years, though splashed with dirt by every passing storm. For more permanent labels, however, it is desirable to use a piece of galvanized-iron wire about fifteen inches long with a coil at the upper end to which a small label is attached. These small labels, called tree labels, may be obtained at slight expense. When more than one word is to go on a label, the first word is written near the top and lengthwise of it, and the second word is written under the first and further from the top. This insures that, as the label becomes less legible in course of time, there will be no

chance of confusing the two words in deciphering them. Labels should be so placed as to stand at the beginning of the rows with the writing facing away from the seeds or plants they refer to. Unless this rule is consistently followed, when several kinds are planted in the same row, there is no way of discovering on which side of the label the plants are that bear the name.

FIG. 104. Proper method of writing labels

Saving seed. In many cases it is as well to save the seeds of desirable crops as it is to buy new supplies of the seedsman annually. For the purpose of seed production one should select the best specimens and take care that inferior stock does not become mixed with it, through cross-pollination. By careful selection one may produce even better crops than the original. It is not desirable, however, to save the seeds of double flowers or of plants that grow near other varieties of the same species, because they are not likely to come true from seed the following year. The different varieties of corn readily mix in this way, and so do plants that produce flowers of several different colors. Seeds should be spread out to dry in a shady place, and when thoroughly dried should be stored in a tin box in a cool, dry place. In warm climates seeds are usually short-lived, and in all regions they require uniform conditions as regards temperature and moisture.

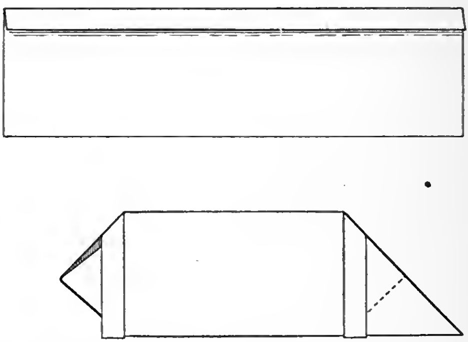

FIG. 105. A seed-tight packet that may be made by simply folding a sheet of paper. See page 146

Table of Seeds and Distances for Planting

Name	How planted	Amount	Will seed	Distances apart of Rows
Beans, bush . . .	drills	quart	150 ft.	18 in.
Beans, pole . . .	hills	quart	125 hills	4 ft.
Beets	drills	ounce	50 hills	12 to 18 in.
Carrot	drills	ounce	100 ft.	12 to 18 in.
Chard, Swiss . . .	drills	ounce	50 ft.	18 to 20 in.
Corn	hills	quart	125 hills	$2\frac{1}{2}$ to 4 ft.
Cress	drills	ounce	100 ft.	1 ft.
Cucumber	hills	ounce	60 hills	4 or 5 ft.
Kohl-rabi	drills	ounce	200 ft.	18 to 24 in.
Lettuce	drills	ounce	200 ft.	12 in.
Melons	hills	ounce	60 hills	5 or 6 ft.
Mustard	drills	ounce	80 ft.	12 in.
Okra	drills	ounce	50 ft.	4 ft.
Onion seed . . .	drills	ounce	125 ft.	1 ft. or less
Parsley	drills	ounce	100 ft.	18 in.
Parsnip	drills	ounce	250 ft.	18 in.
Peas	drills	quart	150 ft.	18 in. or more
Potato	hills	peck	100 hills	$2\frac{1}{2}$ ft.
Radish	drills	ounce	125 ft.	12 in.
Salsify	drills	ounce	75 ft.	15 in.
Spinach	drills	ounce	100 ft.	12 in.
Squash	hills	ounce	25 hills	4 to 9 ft.
Turnip	drills	ounce	150 ft.	12 in.

Vegetables usually Transplanted

Name	How planted	Amount	Will make	Distances apart of Rows
Cabbage . . .	hills	ounce	2000 plants	2 ft. or more
Cauliflower . .	hills	ounce	3000 plants	2 ft. or more
Celery	drills	ounce	5000 plants	2 ft.
Eggplant . . .	hills	ounce	2000 plants	2 ft.
Onion sets . . .	drills	quart	50 ft.	12 in.
Pepper	hills	ounce	2000 plants	2 ft.
Tomato	hills	ounce	2000 plants	3 to 4 ft.

Seed packets. In handling seeds a convenient packet in which they may be placed is desirable. The packet shown in the illustration on page 144 may be made at any time without paste or elaborate manipulation, and yet will hold the smallest seeds securely. To make it, take a sheet of paper of the desired size — 5 inches by 7 inches is a convenient shape — and fold it once the long way of the paper with the two edges together. Next fold back these edges about a quarter of an inch from the edge and repeat the process. Then turning the folded side down with the fold farthest away, bend back the corners

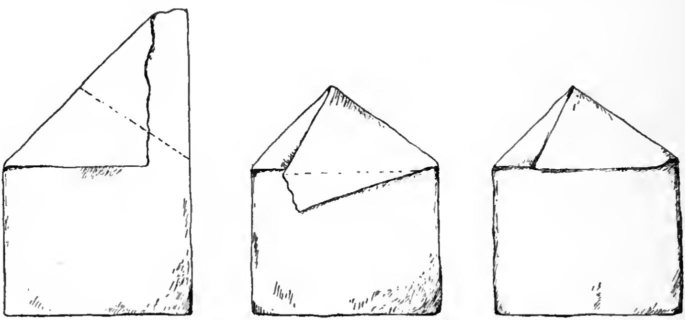

FIG. 106. Method of closing the ordinary seed packet

of the folded side until they meet the opposite edge and form a right angle with it. Next bend the unfolded corners down and tuck the tips under the first fold and the packet is done. When the packet is to be filled either end may be quickly opened. When it is desired to close an ordinary seed packet such as the seedsmen use, fold one corner of the open end three quarters of the way across, fold the opposite corner back upon this, and tuck the tip under the first fold. The illustrations will aid in making this matter clear. All packets of seeds should be carefully labeled with the name of the seeds within and the date at which they were collected. It is unwise to trust the memory for data of this kind which may materially affect the crop.

PRACTICAL EXERCISES

1. Carefully measure the school garden and make a plan of it, drawn to a scale of $\frac{1}{4}$ or $\frac{1}{8}$ inch to the foot. Neatly label all sections.

2. How many acres in the school garden? If less than one, estimate the fraction of an acre. What fraction of an acre is your own part of the school garden?

3. Make a plan, drawn to scale, of an average lot in your town. Allow space for house and lawns and indicate the place in the garden which each vegetable is to occupy.

4. Write to the nearest seedsman for a seed catalogue, which may be had free, and make a list of the vegetables named in your plan; with an estimate of the quantity of seed needed for planting the garden.

5. Make out an order for these seeds, with the quantities and prices, and file with your teacher.

6. Write to your representative in Congress for sufficient seeds to plant your own garden.

7. Get a packet of any large seeds (radishes, beans, or corn will do) and divide it into (*a*) full shapely seeds, (*b*) irregular and small seeds, and (*c*) broken seeds, weed seeds, and dirt. What percentage of the packet is good seeds?

8. Make a seed tester and test twenty large seeds and twenty small ones for vitality. What per cent of each germinated? Which do you conclude would be best to plant?

9. Plant your own part of the school garden and cultivate it after every rain.

10. Try covering half a row of planted seeds with a light mulch. How does this affect the germination of the seeds? Compare with the part of the row left uncovered.

11. Transplant lettuce, beets, cabbage, or other plants to your garden.

12. Select a row of young seedlings planted rather thickly, and thin out half the row to the proper distances between plants and allow the other to go untouched. What effect has crowding?

13. Fertilize half a row of spinach, lettuce, or radishes with nitrate of soda, making two applications about a week or ten days apart. How does the subsequent growth compare with the untreated plants?

14. Plant the seeds of desirable trees and shrubs in the school garden where they may grow into good specimens for use on Arbor Day. If there are small specimens already growing for this purpose, transplant

them to a new location in order that they may develop an abundance of fibrous roots.

15. Properly label all seeds as soon as sown. Make seed packets according to the directions given on page 146.

16. Make a collection of vegetable and flower seeds for the school museum. Have the specimens uniform. Small bottles known as shell vials are excellent containers.

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121. Beans, Peas, and Other Legumes for Food.
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CHAPTER X

TILLAGE

Need for tillage. There are certain factors in crop production that man can do little to change. The range of temperature, the make-up of the air, the amount and time of rainfall, and the amount of sunlight are beyond his power to vary; but the soil, fully as important as any of these, may be greatly modified by his efforts. By drainage he adds to its depth and warmth, by the addition of manures he enhances its fertility, and by proper cultivation he promotes the development of the plants growing in it. Given warmth, moisture, and fertility, tillage is still necessary for the highest development of growing plants. Even wild species become more luxuriant and give finer flowers and better flavored fruits when properly cultivated. The chief difference between our food plants and others of the same kind growing wild is due to the fact that the soil about the food plants is tilled. Tillage renders the soil less compact, enables the roots of plants to penetrate it more easily, adds to its ability to absorb rainfall, prevents the escape of moisture already in the soil, assists the air to penetrate more deeply, thus adding to its warmth and promoting weathering, distributes the bacteria, and discourages the weeds by preventing their becoming established. The great amount of pore space which tillage adds to the soil may be realized by digging a hole in any piece of ground and then endeavoring to put back into the hole all the soil removed. Wherever trenches are dug for pipes or tiling we see an amount of soil left over that, in spite of soaking with water and ramming with heavy instruments, cannot be returned to the trench from which it was dug.

Pulverizing the soil. The soil is pulverized and made fit for crops by *plowing*, *harrowing*, *spading*, and *raking*. In extensive field operations the *plow* is used to break up the soil, while the *harrow*, like a gigantic rake, is used to break up the large clods and level the surface; in the smaller areas, such as the home garden, the same results are attained by the use of the *spade* and the *rake*. The object of plowing or spading

FIG. 107. Plowing

is not only to loosen the soil, but to turn it over, thus bringing new food supplies to the surface and fresh soil into cultivation, while the topsoil, together with such fertilizers as have been applied, is turned under to become fitted for a succeeding crop. In humid regions the soil is stirred to a depth of six or seven inches, but in arid regions the stirring may extend much deeper without harm to the soil. When the soil is underlaid by a stiff and heavy subsoil, the latter is often loosened by *subsoiling* or *trenching*. In *subsoiling* the subsoil plow follows the surface plow in the same furrow but at a greater depth. *Trenching* is restricted to small areas and is

done with a spade. In this operation a layer of soil the width and depth of the spade is removed, forming a trench, and the soil in the bottom of this trench is loosened by spading. Then the trench is filled by the soil from a new trench adjoining it, and so the work continues until the last trench is reached, when the first soil thrown out is used to fill it. The subsoil is often loosened by the explosion of small charges of dynamite. In the home garden the *spading fork* is to be preferred to the

Photograph by H. L. Hollister Land Co.

FIG. 108. Plowing with a tractor

On the larger farms in the West a tractor is often used. With this it is possible to plow a dozen or more furrows at once

spade, since it breaks up the soil more thoroughly and is more easily thrust into stony soil. After plowing or spading, the *harrow* and *rake* are used to further pulverize the soil. The more thoroughly this work is done, the better will be the seed bed. Care must be taken not to work the soil when it is either too wet or too dry, otherwise the soil crumbs will be broken up and the soil puddled. A puddled soil is almost impermeable to air, water, and the roots of plants. Where an old road or path across a field has been plowed up, the effects of

the puddling which it has undergone is often apparent for years in the inferior plants along its course. A heavy rain in summer often puddles the surface layer of soil so completely as to form a crust thick enough to prevent small seedlings from forcing their way up to the surface.

Mulches. Quite as much water evaporates from a saturated soil as from a free water surfaee. As fast as it is removed from the surface, more rises by capillarity to take its place.

Photograph by S. L. Allen & Co., Philadelphia

FIG. 109. Cultivating corn with the horse cultivator

The underside of a board or other objeet lying on the ground is constantly kept wet by the rise of water in this way. A windy day dries up the soil by removing the water as fast as it rises. This steady loss of moisture from the soil can be checked by any sort of loose cover. The mulch of stable manure or other litter often spread on the ground about newly planted trees and shrubs is placed there for this purpose, though such mulches are not desirable for growing

plants because they prevent the stirring of the soil. A layer of dry, porous earth is fully as effective in breaking up the capillary chain. One of the main objects in cultivating plants is to maintain a mulch of this kind, which is commonly called a *dust mulch* or *summer mulch.* The dust mulch is also a great aid to the suppression of weeds, since it contains so little moisture that their seeds cannot germinate. In dry

Photograph by S. L. Allen & Co., Philadelphia

FIG. 110. Cultivating with a wheel hoe

This implement has several attachments and may also be used as a rake, scarifier, or light plow

farming the dust mulch is used to retain the moisture, and so effective is it for this purpose that we are often advised to "water the garden with a hoe"; that is, to keep the water already in the soil from escaping by constant cultivation of the surface. The soil should be loosened after every rain. When plants in large plots are cultivated, the *cultivator*, drawn by

a horse, is usually employed; in market gardens and smaller plots the *wheel hoe*, operated by hand, may be used; while in the home garden the *rake* and *hoe* are most frequently seen. Of the latter there are many styles, ranging from the *shuffle hoes* and *scarifiers* of the expert gardener to the common implement found in every garden. Planting in long rows adds much to the economy in any kind of cultivation and is absolutely necessary when the wheel hoe or cultivator is used.

Anything that decreases the amount of pore space in the soil makes it easier for the water to pass from one soil particle to another, and thus promotes the loss of water through capillarity. Footprints in soft soil show for days, by their darker color, where the moisture is evaporating most rapidly. In planting seeds the escape of moisture is often promoted by compacting the soil about them, the cultivator in this case being willing to sacrifice some moisture in order that the growing seeds may be properly supplied. Covering the soil with a light mulch serves the same purpose.

Work of earthworms and ants. Individually, earthworms and ants are insignificant creatures, seemingly too small to have any effect upon the soil, but when their work in the aggregate is considered, they are seen to be of great assistance in keeping the soil in good condition. The earthworms burrow into the earth, swallowing bits of soil and decaying vegetable matter as they go, and later bring this up to the surface, forming the well-known castings seen about the entrance to their burrows. It is estimated that in this way earthworms bring up from lower levels ten tons of soil per acre annually, nearly an inch in five years. In the course of a century the entire soil as far down as cultivation ordinarily extends would be turned over and very thoroughly pulverized. In addition, the burrows made by these animals aid in keeping the soil porous and well aërated. In dry soils ants take the place of earthworms and turn over the soil nearly as rapidly.

Rotation of crops. In some sections of our country there are farms upon which no other crop than wheat has ever been grown; on others, cotton or corn have been grown continuously. When the same crop has been grown upon one piece of land for a series of years, however, there is a possibility that the soil may be depleted of some necessary element and fail to give adequate returns. Other plants, needing different proportions of the minerals, would be able to thrive where the first crop would fail. Again, certain toxic substances excreted by one set of plants may accumulate in the soil until they put an end to the healthy growth of these plants long before the food materials are exhausted, though these toxic substances are not harmful to other crops. It has been found, also, that when the same crop is grown in the same place for any length of time, the insect and fungous pests that trouble it greatly increase and the weeds associated with the crop multiply. In meadows, daisies often overspread the grasses, and wild mustard thrives in grainfields. Ragweed comes in with the wheat, and smartweed and foxtail grass grow with the corn. The advantages of a change or rotation of crops are thus seen to be many, and everywhere that modern methods obtain, some kind of rotation is practiced. A still further advantage of crop rotation is that it permits the cultivation of deep and shallow-rooted crops alternately, and thus the whole soil is laid under tribute. The usual rotation consists of a grain crop such as oats or wheat, a cultivated crop such as corn, a forage crop such as clover or alfalfa, and, in addition, the field may be used as pasture for a year or more. Somewhere in the rotation it is usually planned to have a legume crop, which, when finally plowed under, enriches the soil by the addition of much nitrogen. Even in small gardens the benefits to be derived from a rotation of crops are worth securing. In nature there is also a more or less well-defined rotation. Ponds dry up and new forms of

vegetation overpower those which grew in the water, cliffs weather to soil and a different flora comes in. In fields allowed to lie fallow the plant covering changes little by little for years, and in the waste places there is always more or less succession of one group of plants by another. In parts of our country there has also been a steady migration of trees into the prairie region since the glacial period, and the movement is still going on.

PRACTICAL EXERCISES

1. Visit the nearest hardware or implement store and examine the machines used in tilling the soil. Make a list of the kinds seen and the uses to which they are put.

2. After a rain mark off 3 sq. yd. in the open ground. Cover 1 sq. yd. with a mulch of leaves or stable manure, pulverize the top layer of soil in the second, and let the third go untouched. At the end of a week examine as to moisture content in the upper layers.

3. In England it has been estimated that there are 53,767 earthworms to the acre. Find the average number of worms to the square foot in the school garden by examining three different spots, and estimate the number to the acre upon this basis. How does your own locality compare with England in this respect?

4. Find out from the farmers near by what the common crop rotations of the region are. Are there any fields in which rotation is not practiced? If so, how do present crops compare with former crops?

5. Make a table of the crop rotations practiced in your county.

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CHAPTER XI

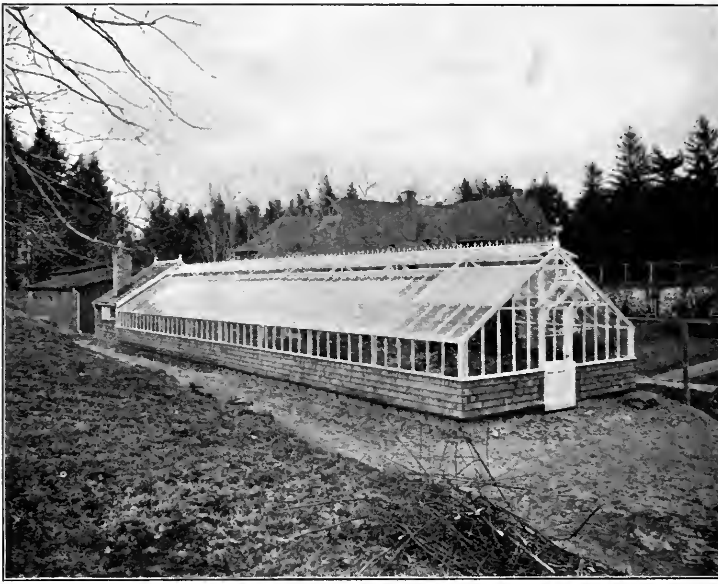
FORCING AND RETARDING PLANTS

Nature of the process. In nature each species of plant has its own season of growth and bloom, determined largely by conditions of temperature, moisture, and the like. Man, by regulating these conditions, creates an artificial season, and hastens, delays, or extends the flowering and fruiting period, thus obtaining his vegetables and fruits "out of season" at any time of the year. Hastening the development of a plant is called *forcing.* This is accomplished by high temperatures, increased moisture, and an abundance of plant food, and results in great succulence and brittleness. Lilies, hyacinths, narcissi, and other bulbous plants are among those that are most easily brought into bloom in this way, either in our homes or in commercial establishments. Owing to the amount of food stored in their bulbs, they may even be forced without soil in which to root, if they are kept supplied with water. On some private estates melons, grapes, peaches, strawberries, cucumbers, and tomatoes are produced in midwinter in houses devoted to this purpose, while the growing of roses, carnations, chrysanthemums, sweet peas, and the like for use in winter is a regular business with the florist. In the vicinity of large cities lettuce, radishes, onions, rhubarb, and asparagus are often grown in this way for the early markets. The business of forcing is carried on under glass in various kinds of houses or shelters, but these all fall under the general heads of greenhouses, cold frames, hotbeds, and hothouses.

Retarding. The operation of holding back the growth of plants for the production of blossoms later is called *retarding.*

This is the exact opposite of forcing. All the early spring flowering plants may be treated in this way, being placed in cold storage until required for blooming. Plants that have started into growth may be retarded to a certain extent by keeping the temperature lower than that required for vigorous growth.

Greenhouses and hothouses. Strictly speaking, a *greenhouse* is a building used for keeping plants green through the winter,



Photograph by Lord & Burnham, New York

FIG. 111. A glass house in which a variety of vegetables and flowering plants may be grown during the winter

and may or may not be heated, depending somewhat on the location, while the *hothouse* is a heated building in which plants may be grown, or warm-climate plants protected, during the winter. Ordinarily, however, this distinction is not maintained and the terms are used interchangeably. A *conservatory* partakes more of the character of the greenhouse, being properly a place for conserving and showing plants

which are grown elsewhere. Plant houses have glass roofs and sides to admit as much light as possible during the short days of winter, and are heated largely by the sun's rays, at least by day. The hotbed has been described as "a trap to catch sunbeams," and the hothouse is merely a larger trap. The heat rays coming from the sun pass through the glass easily, but when reflected back from the soil the glass prevents their escape. The interior therefore warms up rapidly when the sun shines. On bright days the heat may be so greatly increased as to injure or kill the plants if the house is not ventilated. At night and on very cold days the warmth is maintained by some sort of artificial heating system. The first hothouses were kept warm by quantities of fermenting manure placed in pits beneath the benches upon which the plants were grown, and such means may still be depended upon to keep the frost out of small houses during the winter. In general, however, some sort of hot-water heating system is used.

Hotbeds. Hotbeds are really small plant houses kept warm by fermenting manure and the sun's heat, and are used for growing plants before the weather will permit of their being grown in the open. Early crops of lettuce, radishes, and other vegetables are raised in this way, and long-season crops, such as tomatoes, peppers, and eggplants, are started here and carried along until transplanting time. To make a hotbed, a pit should be dug 2 feet deep and about 1 foot wider than the frame that is to be placed over it. This pit is to be filled with manure to supply the heat, and should contain a good share of straw or other material in order that the heat may be long continued. The manure should be placed in a pile and forked over at intervals for several days before using, to insure that the fermenting material has been thoroughly mixed through it. When the whole pile is steaming it should be placed in the pit in layers about 6 inches deep, and each layer

thoroughly tramped down. Over the pit of manure a layer of good soil 6 inches deep should be spread, and in this the plants are grown. The hotbed frame is made of boards, and the roof, which is made of one or more hotbed sashes, should slope toward the south. The front of the bed may be 6 inches or 1 foot high and the back 12 to 20 inches. Hotbed sashes are 3 by 6 feet in size, and the frame is made about 6 feet wide and long enough to take one or more sashes. Old window sash may be used if hotbed sash are not at hand. When the manure is first put into the pit and the sashes put on, the heat often rises too high for plant growth. Seeds should not be planted until the temperature at midday falls below 90°. The frame is usually banked up on the outside with manure as an additional protection from the cold, and on very cold nights the glass should be covered by mats, old carpets, or a layer of straw. Hotbeds are sometimes made upon a level pile of manure placed on the surface of the ground. In this case the manure should project beyond the frame at least a foot on all sides. The heat in a hotbed is not sufficient to carry it through the entire winter, and its use is usually confined to the late winter and spring. In the Northern states the hotbed is not begun much before the middle of February, and in many cases the middle or end of March is early enough. In managing the hotbed care should be taken to give the plants air whenever the weather is favorable. This may be accomplished by lifting the lower end of the sash and placing a block under it, or on fine days the sash may be shoved part way off the frame. Plenty of air tends to make the plants sturdier.

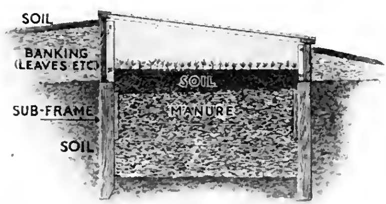


FIG. 112. A hotbed showing the details of construction

Cold frames. The cold frame differs from the hotbed in a single feature: it lacks the pit of manure. It cannot therefore be used for growing plants in very cold weather, though as the air becomes warmer in spring it is often used to start tomato, cabbage, and other plants for transplanting. Its greatest usefulness is found in carrying half-hardy plants over the winter and in prolonging the growing season of lettuce, radishes, pansies, and the like in autumn. Cold frames are banked up with manure to aid in keeping out the frost, and in severe weather may be covered with mats. Both cold frames and hotbeds do best if placed in sheltered situations, though cold frames for carrying half-hardy or dormant plants through the winter are often placed on the north side of a fence or building. In the latter case the object is simply to protect the plants, and no light is needed. Cold frames designed to shelter plants for a few weeks in spring may be made with oiled paper or cloth in place of the glazed sash.

Forcing single hills. Single plants of such species as rhubarb, asparagus, and sea kale may be made to grow much earlier than they would naturally, by placing a box or half barrel over each hill and piling manure around it. The top is sometimes covered with a light of glass, thus making a miniature cold frame of it. Single boxes of this kind are now being offered for sale and serve a variety of purposes. In autumn manure is often piled over hills intended for forcing, to keep the ground from freezing deeply. Asparagus, rhubarb, and onions are often forced in the house by setting the "roots" upright and close together in a box and placing the box in a warm room or cellar. If kept moist, the young shoots will soon appear. These plants may also be grown under the greenhouse benches in the same way. Light is not necessary for forcing plants of this nature, since the food stored in the roots or other underground parts is drawn upon for making shoots. If it is desired to force the same roots again, they

must be set out in spring in good soil and allowed one or more years in which to recuperate.

Etherization. A large number of plants that form their flower buds at the end of the growing season do not readily resume growth when kept in sufficient warmth. These same plants, however, if allowed to remain dormant and brought into warmth at the end of winter, begin at once to grow. From this it is seen that plants require a season of rest, and if we are to induce such species to bloom in midwinter, something to take the place of this rest must be devised. Freezing, as a substitute for rest, has been found useful. If rhubarb plants designed for indoor forcing are carried in before frost, they fail to make proper growth, but if dug up in the field and exposed to a few frosts, they grow at once when planted. Heat appears to have the same effect as cold, and many species may be as easily forced by plunging their branches into hot water for a short time. Drought also affects plants like cold, and some specimens behave in the same way if treated with ether. In *etherization* the plants are placed in an air-tight receptacle and exposed to the fumes of ether for twenty-four hours or longer. When brought into warmth they are ready to grow, the ether appearing to have the same effect upon them as the long rest through the winter. Lilacs etherized in August have been brought into full bloom a few weeks later. In etherization about one third of an ounce of ether to each cubic foot of space is the right amount.

Forcing plants in the window garden. The conditions in most dwellings are not favorable to plant growth, especially in winter. The dryness of the air, the lack of sunlight, the presence of coal gas and illuminating gas in the air, and the difference between the day and night temperatures all conspire to kill or enfeeble vegetation. Only the hardiest plants can be induced to grow and bloom under such circumstances. Plants produced from bulbs, corms, and the like are an exception to

this, since the food necessary for their growth and even the blossoms themselves are formed in the underground parts during the preceding season. If given sufficient water they are able to develop their flowers with very little light, since blossoming with them is largely a mere expansion of parts already formed. They may be grown in soil or water, but in either case they are usually set aside in some cool dark place, after planting, to form roots before being placed in the light. The most popular subjects for growing in this way are the paper-white narcissus and the Chinese sacred lily, a closely related species, but tulips, crocuses, hyacinths, and other bulbous plants are also grown. After flowering, the plants are usually thrown away, since they cannot be satisfactorily forced a second time.

PRACTICAL EXERCISES

1. At the proper time make a hotbed or cold frame in the school garden and plant in it seeds of long-season plants that may be transplanted to the open ground later. Make a sowing of lettuce, beets, or onions for transplanting.

2. Dig up spring flowering plants before they start into growth and place in cold storage, to be brought out and flowered when those in the fields have gone.

3. Try forcing sea kale, asparagus, or rhubarb.

4. Make a single forcing hill for growing some plant from seeds, such as melon.

5. Try forcing some wild plant at the beginning of winter. Etherize another plant of the same kind and compare results.

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CHAPTER XII

WEEDS

Definition of a weed. A weed is properly defined as a plant out of place. No matter how beautiful the flowers may be, or how highly the species may be regarded for decorative planting, if it competes with cultivated plants for possession of the soil,

Photograph from American Steel and Wire Co.

FIG. 113. Spraying a field of young grain with iron sulphate to eradicate mustard and other weeds

it is a weed. In some localities the worst weeds with which the farmer has to contend are ferns. Many species that in foreign lands are cherished as beautiful flowering plants are counted mere weeds at home. Indeed, some of the weeds that now bother our cultivated crops, such as bouncing Bet and

toadflax, were originally brought from Europe as desirable additions to the flower garden, and only later took up a free life in the fields. A few of our weeds are native, but most of our noxious species have been derived from the Old World, where centuries of struggle with crop and cultivator have developed to the utmost their ability to resist all attempts to dislodge them. Nor are weeds entirely confined to specimens growing in cultivated areas. The plants that come up in walks

Photograph from American Steel and Wire Co.

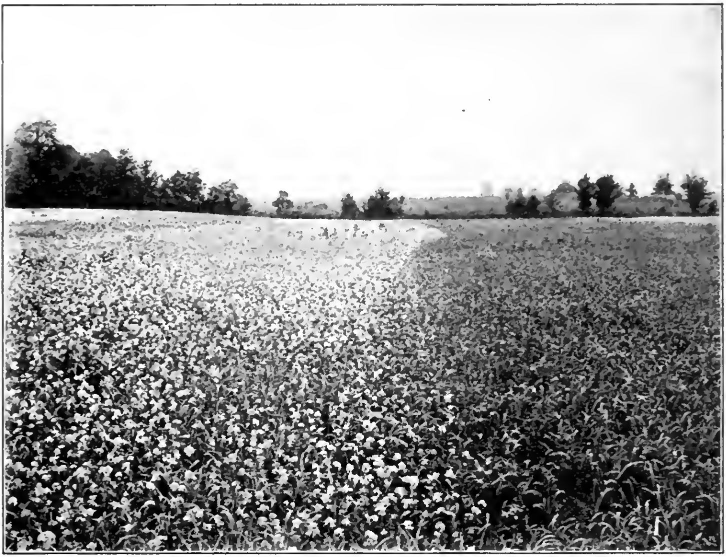
FIG. 114. Grainfield showing the effect of spraying with iron sulphate

The portion on the left is unsprayed. Note the abundant young mustard plants

and drives, on railway embankments, and in similar places are weeds. Other weeds, like the ditch moss and water hyacinth, are confined to the water, but prove their weediness by choking up the streams and rivers, and in some cases actually preventing navigation.

Harmfulness of weeds. Weeds are harmful in several ways. They absorb water needed for the growth of cultivated crops, prevent the formation of plant food by shading, harbor fungous and insect enemies, render more difficult the task of keeping

the soil loose and open, and in many cases their seeds gathered with the crop injure its value. Weeds should not be allowed to grow even in the borders of cultivated grounds, since from this point they may seed the soil for several years to come. In this connection it is well to remember the oft-quoted maxim, "One year's seeds, seven years' weeds."



Photograph from American Steel and Wire Co.

Fig. 115. A grainfield showing wild mustard in blossom. The portion on the right has been sprayed with iron sulphate

Nature of weeds. Some of the qualities that conduce to weediness in plants are abundant and easily distributed seeds, the ability to grow rapidly, to endure injury and shading, and to thrive upon little moisture and in sterile soils. Many secure immunity from grazing animals by offensive odors, prickly leaves and stems, and other disagreeable characteristics. Some are winter annuals that grow in spring before more valuable crops have started; others are summer annuals that wait until

the crops are well along, but grow so rapidly when they do appear that they soon overtake and choke out their competitors; while still others are perennials that spring again and again from underground parts after being cut down by the gardener. A few are *mat plants* or *rosette plants* that form dense carpets over the soil, and some are vines that climb on other plants, but the great majority simply grow erect and take the ground by virtue of a more luxuriant growth.

Photograph from American Steel and Wire Co.

FIG. 116. Spraying a lawn with a hand sprayer to eradicate weeds

Eradicating weeds. One of the most effectual methods of eradicating weeds is to prevent them from seeding. All annual species are easily held in check in this way. When crops are frequently cultivated the weeds are unable to get a start. A favorite way of clearing a field of weeds is to plant it for one or more seasons to some crop that must be hand cultivated. All weeds may be killed by applications of salt, but since what will kill weeds will also kill more valuable plants, this method cannot be used except on walks, drives, and similar places. Asparagus, however, can stand an application of salt strong enough to kill the weeds that grow with it. Plants which

depend upon peculiar soil conditions may be eradicated by changing these conditions. Sedges which delight in moist soil may be exterminated by draining, and mosses, sorrel, and various other plants that like acid soils may be driven out by liming the soil. Perennial plants must either be starved out by frequently cutting off the leaves, or they may be dug up. A large number of weeds are also killed by spraying with *iron sulphate*, or "copperas," in the proportion of six pounds of iron

Photograph from Bergen and Caldwell's "Practical Botany"

FIG. 117. A tumbleweed (*Cycloloma*) blown into heaps by the wind

sulphate to four gallons of water. Grainfields may be practically freed from wild mustard in this way, the spray doing no harm to the cultivated plants. All crops are not so resistant and one must discover what the particular requirements of a crop are before spraying. For destroying algæ, the fine, filamentous green growths that often appear in lily ponds and the like, *copper sulphate* is often used. The water should be treated with one part copper sulphate to three million parts of water. Fish are very easily poisoned by this substance, and care must

be taken not to have it too strong if used in ponds in which there are desirable species.

Not all weeds are equally noxious; moreover, what may be a bad weed in one locality may be comparatively harmless in another, perhaps because the crops are different, but there are some species whose reputation for noxious qualities is world-wide. Some of these are listed here. Other and more local species may be studied in books devoted to the subject.

Photograph from American Steel and Wire Co.

FIG. 118. Dandelions gone to seed on a neglected lawn

Purslane (*Portulaca oleracea*). This is a fleshy little mat plant with small yellowish flowers that open only in sunshine, and is related to the portulaca, or rose moss, of our flower gardens. It will grow in almost any soil, and stores so much water in its thick leaves that, after it has begun to bloom, it can ripen its seeds though severed from the soil.

Spreading amaranth (*Amaranthus blitoides*). This species resembles the purslane, but it is larger, less fleshy, and has clusters of insignificant greenish flowers. Single specimens may form mats more than a yard across.

Green amaranth (*Amaranthus hybridus*). This is also known as redroot and pigweed. It grows to the height of several feet, with broad coarse leaves topped by a dense pyramid of greenish flowers. It is a most abundant and well-known weed, but is easily exterminated.

Photograph from American Steel and Wire Co.

FIG. 119. The common plantain

Tumbleweed (*Amaranthus albus*). Before the advent of the so-called Russian thistle this was the best-known tumbleweed. It is a rather low plant with branches disposed in globular form. When mature, the whole plant separates from the root and is blown about the country, scattering the minute seeds as it goes.

Pigweed (*Chenopodium album*). This weed is also known as lamb's quarters. It is a pale green plant with somewhat triangular leaves that are whitened by a mealy deposit, and is thus easily recognized. It is a close ally of the beet and spinach and is often eaten as a pot herb.

Russian thistle (*Salsola tragus*). This plant is in no sense a thistle, being more closely related to the pigweeds. It is extremely prickly, and from this circumstance its name is derived. It is another of the tumbleweeds and in consequence spreads rapidly. It is well known in the Middle West, where it was accidentally introduced during the latter part of

the last century, and is now a familiar plant in waste grounds, roadsides, railway embankments, and the like.

Spotted spurge (*Euphorbia maculata*). The spotted spurge is another of the mat plants, and is readily distinguished by its small, thin, hairy leaves with a red blotch in the center, and by its much-branched slender stem, pressed close to the earth. The juice is milky. It delights in dry open places and grows readily in soils too sterile for the growth of other plants.

Photograph from American Steel and Wire Co.

FIG. 120. A tangle of the common bindweed

Dandelion (*Taraxacum officinale*). Its yellow flowers and feathery heads of seeds make this most abundant rosette plant too well known to require description. Its long and fleshy taproot is often removed by digging, but if any is left in the soil, it may originate new buds and produce a dozen or more plants where but one was originally.

Plantain (*Plantago* sp.). Three species of plantain are frequent as weeds in grassy areas. Of these, *Plantago major*

and *P. Rugelii* are common dooryard weeds with broad and rounded leaves and slender spikes of inconspicuous flowers. The third species, the narrow-leaved plantain (*P. lanceolata*), is easily distinguished by its rosette of long narrow leaves veined lengthwise of the blade. All the plantains are easily dug up.

Photograph from American Steel and Wire Co.

FIG. 121. A common wild lettuce related to the prickly lettuce

Common bindweed (*Convolvulus sepium*). The large white or pink funnel-shaped flowers, like morning-glories, make the bindweed conspicuous and well known. It is fond of rich soil and forms tangled mats over the vegetation in the fields where it grows. It has a creeping underground rootstock that makes it one of the hardest of weeds to eradicate.

Black bindweed (*Polygonum convolvulus*). The climbing stems of this plant overrun other plants in its vicinity, after the manner of the common bindweed, to which, however, it is not closely related. It is a much slenderer plant with greenish flowers and seeds that suggest its relative the buckwheat. Being annual instead of perennial, it is a much less formidable species than the common bindweed, though its vigorous growth makes it a harmful weed.

Prickly lettuce (*Lactuca scariola*). Although the introduction of this plant into America occurred but recently, it has already spread so extensively as to become a common weed. It may be known by its erect prickly stems and bluish-green leaves, most of which are turned edgewise and point north and south. It is frequently a winter annual and is regarded by botanists as being the parent of our garden lettuce.

Ragweed (*Ambrosia artemisiæfolia*). Ragweed, a homely plant with much-dissected leaves, is found almost everywhere in cultivated land. At flowering time the insignificant greenish-yellow flowers shed great quantities of yellow, dustlike pollen, which collects upon the shoes and clothing of all who pass through it. The pollen is regarded with good reason as being one of the causes of hay fever.

Photograph from American Steel and Wire Co.

FIG. 122. Ragweed, a common weed regarded as the cause of hay fever

Wild mustard (*Brassica arvensis*). Several species of mustard are known under the general name of wild mustard, but the species named above is the most widespread and troublesome. The mustards may be distinguished by their coarse hairy leaves, clusters of bright yellow flowers, and long spikes of seed pods. They spring up quickly, grow rapidly, and soon smother less strenuous plants. The turnip is a closely related species of *Brassica*.

Oxeye daisy (*Chrysanthemum leucanthemum*). The large white flowers of this species, universally known as daisies or marguerites, are sufficient to identify it. It is a perennial, spreading rapidly by means of its many small seeds, and becomes a bad weed in meadows and pastures, crowding out the rightful tenants of the soil. It is sometimes known as whiteweed. The yellow daisy (*Rudbeckia hirta*), also common in fields and meadows, is a native species.

Photograph from American Steel and Wire Co.

Fig. 123. A plant of wild mustard

This species is especially harmful in grainfields

Canada thistle (*Cnicus arvensis*). Many other species of thistle are confused with this much-dreaded plant, which, in spite of the name it bears, is an Old World species, and not a native of this continent. It may be known by its very prickly stems and leaves and its pale lavender blossoms of small size. Owing to the fact that its rootstock is widely creeping and deep in the earth, it is very difficult to eradicate when once established. The plant has two kinds of blossoms, those on some specimens being completely sterile. This has given the impression in some sections that the plant does not ripen good seeds in parts of its range.

Quack grass (*Agropyrum repens*). This is a perennial species whose slender and wide-creeping rootstock sends up new stems at frequent intervals that later bear slender close-set spikes of greenish flowers. It is one of the hardest of weeds to root out, but this may be accomplished by planting fields infested with it to some hoed crop and cultivating frequently. Though so generally useless, this species is closely related to the wheat.

Photograph from American Steel and Wire Co.

FIG. 124. The oxeye daisy on the border of a field

Crab grass (*Panicum sanguinale*). This species, often called finger grass, is a coarse annual that does not begin to grow until the weather is quite warm and the cultivated crops well started. At first the stems are erect, but later they lie upon the soil with only the tips erect, and root wherever a joint comes in contact with the earth. When pulling it up, every root must be loosened or it will continue to thrive. The flowering stems are topped by several slender spikes that radiate from a common center.

Foxtail (*Setaria glauca*). This is another annual grass that does not make its appearance until very late in spring. It has a most extensive root system, and when it is pulled up often brings more valuable plants with it. The fruiting part is a bristly spike two or three inches long, from the appearance of which the common name is derived.

Photograph from American Steel and Wire Co.

FIG. 125. Young plant of the Canada thistle, one of our worst weeds

Old witch grass (*Panicum capillare*). This is an annual that thrives in dry soils. It appears in early summer, putting up several coarse hairy stems that bear large panicles of many purplish threadlike divisions. Late in the year these panicles break from the plant and are blown about by the wind. This species is sometimes called tickle grass in allusion to its feathery panicle.

Buttercup (*Ranunculus acris*). Several species of buttercup may become weeds, but the one here given is best entitled to the name. It takes entire possession of many damp meadows and is so acrid that cattle will not touch it. Drying dispels the acrid properties, and when cut with the hay it is harmless.

Wild carrot (*Daucus carota*). The wild carrot is also called bird's nest and Queen Anne's lace, in allusion to its flower clusters. It is a vile pest in many thin soils and its sturdy

taproot makes it hard to conquer. The plant is supposed to be identical with the cultivated carrot, but in the wild state it is reputed to be poisonous.

FIG. 126. Wild carrot on a neglected lawn

Sorrel (*Rumex acetosella*). This plant, commonly known as sour grass or horse sorrel, is a perennial weed with numerous creeping subterranean stems and thrives in sterile soil. Early in summer it turns its haunts a rusty red by a multitude of small flowers. It is supposed to be an indicator of acid soils and may be controlled by the application of lime.

Photograph from American Steel and Wire Co.

FIG. 127. A field overrun by wild carrot

Other weeds. Among less noxious though ever-present weeds may be mentioned shepherd's-purse (*Capsella*), pepper-grass

(*Lepidium*), chickweed (*Stellaria*), knotgrass (*Polygonum*), burdock (*Arctium*), evening primrose (*Oenothera*), sneezeweed (*Helenium*), bugloss (*Echium*), bouncing Bet (*Saponaria*), toadflax (*Linaria*), smartweed (*Polygonum*), dog fennel (*Anthemis*), and Jimson weed (*Datura*). These may be looked up in any botanical manual. A large number of other plants, such as yarrow (*Achillea*) and sheep sorrel (*Oxalis*), come

Photograph from American Steel and Wire Co.

FIG 128. A plant of dog fennel, a common weed along roadsides and in low grounds

under the designation of weeds, since they frequently grow among cultivated crops, but they are seldom harmful enough to be classed with the noxious species and are not difficult to eradicate.

It should not be supposed that the plants we now recognize as weeds are the only ones with which the cultivator is likely to have to contend. New weeds are practically certain to appear from time to time, either derived from our native flora

or as immigrants from other parts of the world. The orange hawkweed (*Hieracium aurantiacum*), which within a generation has spread over large areas in the Eastern states, is a case in point, and the Russian thistle, which appeared somewhat earlier, is another. The rapidity with which these weeds have spread is accounted for by their methods of seed distribution. Plants with wind-distributed seeds are usually good travelers, but those whose seeds lack special means of distribution are often very slow in conquering new territory. The oxeye daisy, which has proved such a pest in New England, is still rare or absent in the north-central states, while the yellow daisy, originally a Western plant, has spread to the East in comparatively recent times. New weeds are likely to be first found along traveled ways, especially if their seeds are not modified in some way for distribution, and a new line of traffic is usually responsible for their introduction. *Galinsoga parviflora*, a harmless Mexican plant, was unknown in the Northern and Eastern states until the inhabitants began railway traffic with Mexico. Now it is common in many places as far north as Canada. The teasel is an Old World plant that has long been known as a weed in America,

Photograph from American Steel and Wire Co.

FIG. 129. Yarrow, a nearly harmless weed of wide distribution

but it is still rare except in the vicinity of railroads. Other weeds owe their appearance in new regions to their having been brought in with the seeds of cultivated crops. The corn cockle (*Agrostemma githago*) owes its common name to the fact that it is nearly always found in grainfields, where its seeds have been carried with the grain.

PRACTICAL EXERCISES

1. Make a list of the weeds known to grow in your locality.

2. What qualities make them bad weeds?

3. Make a list of the weeds that spring up in the school garden.

4. Underscore the weeds in the above lists that are perennials.

5. Make a collection of weed seeds labeled with both scientific and common names.

6. Make a list of the ways in which these weed seeds are distributed, with examples of each.

7. Estimate the number of seeds produced by one weed in a season. If all these seeds should grow the following year and produce the same number of seeds and continue to reproduce in this way, how many years would it take to produce one plant for each acre of land in the world?

8. Make a list of weeds that have come into your region with the seeds of cultivated crops. Make a similar list for those that have come in along the railroads.

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CHAPTER XIII

PROPAGATION

Natural methods. The one means by which all plants higher in the scale of life than the ferns are multiplied is by seeds. Many species, in addition to this, have devised various ways of multiplying *asexually* or *vegetatively* by means of special parts of the plant which take root and soon become separate individuals. This latter method is often more certain than reproduction by seeds, since the new plant may remain attached to the old one until established; and some species, such as the potato and horse-radish of our gardens, and the sugar cane and sweet potato, have almost abandoned seeds in favor of it. In most cases, however, seed production and vegetative multiplication proceed side by side, one being used for multiplying the plant in a particular station and the other for spreading it into other regions.

FIG. 130. A lilac shrub that has produced numerous suckers

Typical forms for propagation. The branches of almost any plant may strike root under favorable circumstances, but in plants that depend very much upon vegetative methods there are usually well-defined parts developed for the work. Several of these have received distinctive names, such as sucker, stolon, offset, tuber, rootstock, bulblet, and cormel. A *sucker* is produced by an adventitious bud upon some underground part, usually a root. Many plants, among which may be mentioned the lilac, plum, locust, and white poplar, sucker freely. In such species injury to the root or cutting back the top may induce suckering. A *stolon* is a slender branch that bends over and roots at the tip, as in the black raspberry, currant, June berry, and golden bell. The *offset* is a short, thick, horizontal branch, either on the surface or underground, which produces a plant at the tip. It differs from a stolon chiefly in being shorter and thicker and designed solely for reproduction. The century plant, house leek, and ostrich fern produce numerous offsets. *Runners* differ from offsets mainly in being slenderer and longer, and in producing new plants at each node, as in the strawberry. *Tubers* are short, much thickened underground branches that lie in the soil over a season of cold or drought and produce new plants upon the return of a more

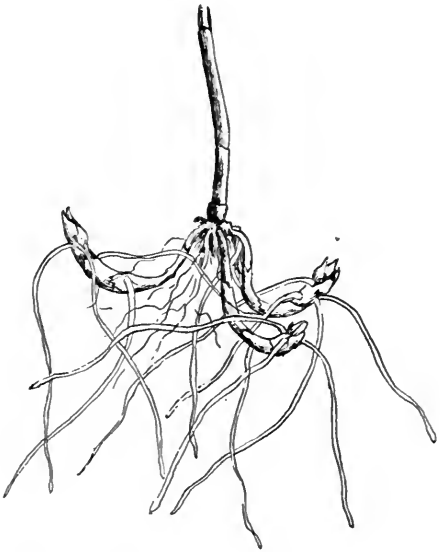

FIG. 131. Base of a sunflower stem showing offsets for reproducing the plant

favorable season. The potato and artichoke are good examples. *Rootstocks* are also subterranean stems, but differ from tubers

FIG. 132. Onion bulbs
The sectioned specimens show the origin of bulblets

in being the main axes of the plants instead of branches, and in living much longer. When the rootstock branches, however, these shoots act exactly like tubers in forming new plants. The iris and Solomon's seal are good illustrations of rootstocks. *Bulblets,* or *bulbils,* are budlike structures, really small buds, produced in the axils of bulb scales, as in many lilies and the "potato" onion, or on the aërial parts of plants, such as may be seen in the tiger lily and the "top" onion. *Cormels* are small condensed stems with one or more buds, and are produced by corms, such as the gladiolus and crocus.

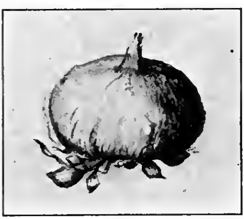

FIG. 133. A corm of gladiolus with several small cormels attached

Artificial propagation. In multiplying his specimens the gardener takes advantage of all the methods evolved by

plants, to which he adds various others which careful manipulation and a knowledge of plant growth make possible. Often injury to the plant will cause it to produce parts designed for reproduction. Cuts near the base of bulbs or corms will cause bulblets or cormels to develop. Even bulb scales, when treated as softwood cuttings, may develop into new plants. All vegetative multiplication depends upon a division of the plant, which fact may be made use of in many ways. Cormels and bulblets are removed from the plant and treated like seeds. Rootstocks are separated into bits, each of which contains one or more buds and a few roots. Tubers, like rootstocks, are cut into pieces, a single specimen thus producing several new plants. Runners, offsets, stolons, and suckers are separated from the parent plant and set where wanted. Other species, such as the phlox,

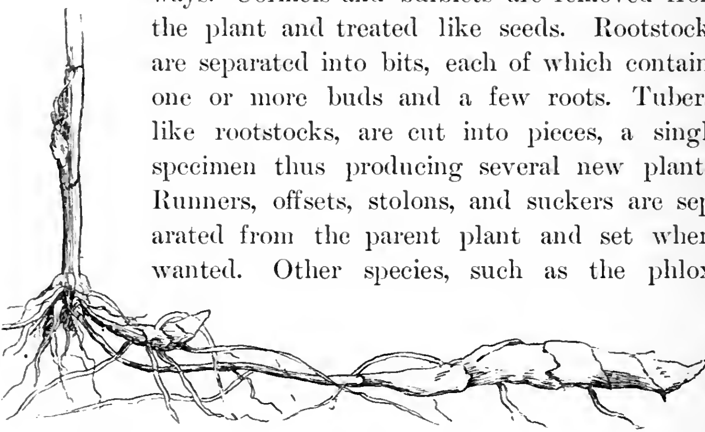

Fig. 134. A species of sunflower (*Helianthus laetiflorus*) showing the evolution of a tuber from an offset

golden glow, and chrysanthemum, which grow in clumps without well-defined rootstocks or other means of propagation, may be simply cut in pieces and each piece planted separately. Chief among the artificial methods which man has devised for multiplying plants may be named cuttings, layering, budding, and grafting.

Cuttings. Nearly all plants may be increased in number by detached parts, which, placed in moist sand or even water, soon strike root and become independent individuals. The "slips" by which house plants are commonly propagated are

good examples. These cuttings are placed in two groups: *green* or *softwood* cuttings, made mostly from herbaceous plants and intended to be rooted at once; and *hardwood* cuttings, made from woody plants late in autumn. The latter are kept in a dormant condition through the winter and are rooted the following spring. This latter form of cutting is the one commonly employed in multiplying the woody plants, but many of these may also be propagated by softwood cuttings, especially roses, currants, golden bell, willow, and poplar. For this purpose the cuttings should be taken while the wood is young and tender. In making any kind of cutting it is desirable that the cuts be made just below the nodes, since the new roots usually spring from these parts. Among the plants commonly grown from softwood cuttings are carnations, geraniums, begonias, chrysanthemums, and those specimens known as "foliage plants." When set, about one third of each cutting should project above the soil. To prevent loss of moisture while they are making roots, it is customary to remove part or all the leaves before setting and to protect them from the drying effects of the air by sheltering with glass or thin cloth. Plenty of warmth and moisture is necessary to make most cuttings root rapidly, but they should not be kept so close as to prevent ventilation. The hardier plants, however, will root if the

FIG. 135. A geranium cutting which has struck root

From Bergen and Caldwell's "Practical Botany"

cuttings are merely stuck in moist soil in a shady place. Several forms of softwood cuttings have distinctive names. *Leaf cuttings* are made from leaves or parts of leaves, which are pegged down on moist sand and kept close. After a time

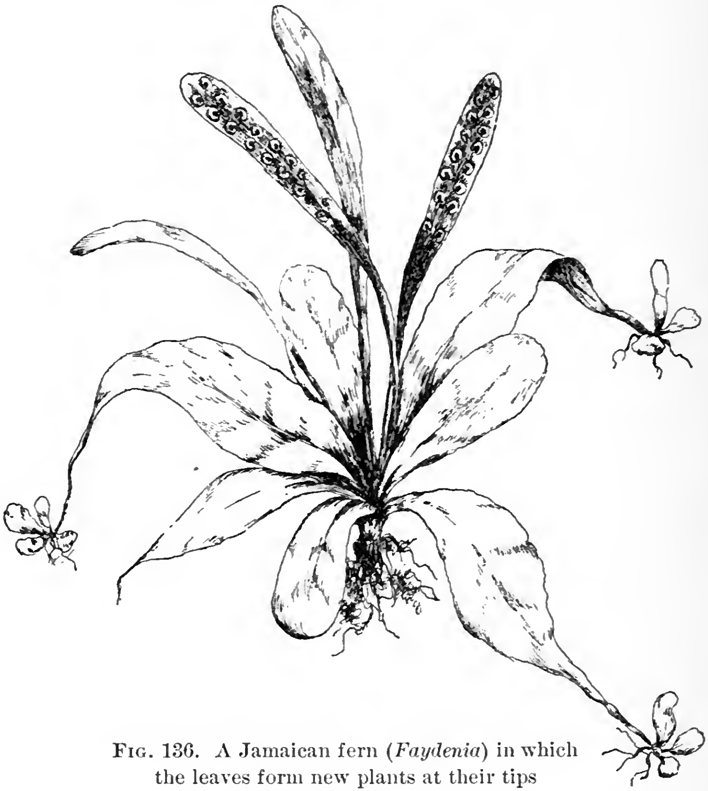

Fig. 136. A Jamaican fern (*Faydenia*) in which the leaves form new plants at their tips

tiny plants will begin to form along the edge of the leaves. Begonias, wax plants, and bryophyllums are multiplied in this way, and among wild plants the sundews and many ferns have the same faculty. *Stem cuttings* are the ordinary "slips" or twigs taken with three or more joints. *Tuber cuttings* are pieces of tubers with one or more "eyes," or buds. Cuttings

of this kind are the customary means of multiplying potatoes, artichokes, and dahlias. *Root cuttings* may be used for getting additional plants of quince, horse-radish, blackberry, sea kale, phlox, butterfly weed, and the like. In such cases adventitious buds are formed on the roots, although they do not normally occur in this way. In the case of phlox and butterfly weed, however, small roots left in the soil after the plant is dug are almost certain to send up new plants, and in horse-radish and sea kale the larger roots are depended upon for increasing the number of plants. Dandelion roots can also originate buds

FIG. 137. Tubers of artichoke (*Helianthus*) and potato, which are usually propagated by tuber cuttings

in this way, and a single piece of root left in digging may produce several new plants. Root cuttings, like tuber cuttings, are entirely covered by the soil when planted.

Hardwood cuttings. Hardwood cuttings are made from mature wood not more than two years old and usually younger. They are cut at least six inches long and are taken late in autumn when the wood is dormant. They are not set until the following spring and must be kept in a cool moist place until used. In common practice they are tied in bundles of about one hundred each and buried a foot or more deep and upside down in a well-drained spot, or they may be kept in moist sand in a cool cellar. During the winter a tissue called the *callus* forms over the cut ends, and from this or near it the new roots start. In plants that root rather easily the cuttings are often set out in autumn. Nearly all our trees, shrubs, and woody vines may be propagated by hardwood cuttings, though the form of these depends somewhat upon the species it is

desired to multiply. Besides the simple cuttings of three or more joints, there are *single eye cuttings* consisting of a single node with its buds. These are planted in the soil, usually in the greenhouse, and treated as if they were seeds. *Heel cuttings* are made by removing a twig with part of the old wood attached to it, the latter forming the "heel." *Mallet cuttings* are sections of the main stem with the twig attached. In some species, especially those with very hard wood, these latter root more readily than the simple stem cuttings. In general, hardwood cuttings should be set so that not more than one bud appears above the soil.

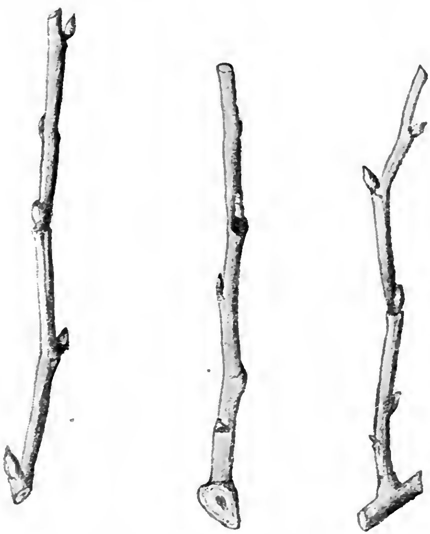

Fig. 138. Three forms of hardwood cuttings

On the left, the ordinary form; in the middle, a heel cutting; on the right, a mallet cutting

Layering. Layering is a modification of reproduction by cuttings used with plants that do not readily strike root from separate pieces. In this method the twig is induced to strike root, while still attached to the parent plant, by being bent down and covered with moist soil. Often the branch is cut part way through where it is covered with soil, or it may be bent or twisted, or a layer of bark may be removed to further influence the production of roots. The black raspberry, hobblebush, and golden bell root naturally at the tips, and other plants may be made to do so. This is called *tip layering* and is really the forming of an artificial stolon. In *vine layering* the branch may be covered with

soil at several points, and when these form roots, they are cut up into separate plants. Grapes, honeysuckles, wistaria, and many others may be propagated thus. Branches that rise from the base of shrubs often form roots and may be removed to form new plants. This process is often hastened by the grower, who first cuts back the plant to make it throw up numerous shoots and then heaps the soil up around them so that they will root. This is known as *mound layering*. What is essentially a form of layering may be often seen in greenhouses where various tropical species, such as the rubber plant, are multiplied by tying a ball of wet moss about a branch near the tip, first injuring the bark to make it root at that point. The moss is kept wet and in due time is filled with roots, after which the branch is cut off. This is called *air layering* or *pot layering*.

The sand box. Although established plants thrive only in rich soil, cuttings root better in clean, sharp sand. The willow, wandering Jew, and nasturtium root readily in water. The nurseryman roots his cuttings in beds of moist sand in the greenhouse, but for home work a box of sand set in a shady place and covered with glass or thin cloth is very useful. Care should be taken to see that the sand is free from injurious fungi and insects, and after being used for one lot of cuttings should be sterilized by baking or pouring boiling water through it before it is used for another. The cuttings should be given a warm and even temperature and should not be allowed to suffer for water or fresh air.

Budding. Budding does not increase the number of plants, but it may be employed to increase the number of a certain kind. It is really a form of transplanting whereby the bud of a desirable species is made to grow upon one less desirable and thus change the nature of the plant. It is used for making worthless species productive, for multiplying forms that will not come true from seeds, and for hastening the fruiting

of others. All of our superior fruits and many of our nut trees are budded or grafted upon other stock because their characters are not fixed in the seed. Having one good plant, however, we may make as many others as we choose by budding. In this process it makes no difference if the fruits produced by the stock are worthless. The bud will form a new crown that will produce fruits like the plant from which it was taken. In growing the stocks, therefore, seeds from any source may be sown. The plants are budded when one or two years old, and thereafter have all the characteristics of the superior strain. Usually only closely related forms can be budded successfully. The plants most frequently treated in this way are the stone fruits, nut trees, and some of the citrous fruits. Budding is performed in late June, July, August, and early September.

Fig. 139. A twig with buds removed for budding

Method of budding. In the common form of budding a T-shaped cut is made in the bark of the stock, the upper edges of the cut are carefully turned back, and a new bud with more or less bark attached is inserted, after which the bark of the stock is pressed into place and tied for a week or more until the bud has grown fast. The cut in the stock should go halfway around the twig or stem, and the cut at right angles to it should be about an inch and a half long. Both should extend inward as far as the new wood. The bud should be selected from a vigorous and healthy plant, and removed with an upward cut of a sharp knife, beginning a quarter of an inch below the bud and ending the same distance above it. The cut should be made just deep enough to remove a thin shaving of the new wood, which may afterwards

be removed with the knife, or, if very thin, it may be inserted with the bud. The leaf that occurs below each bud may be severed where the blade joins the petiole, and the latter left for a handle. The bud and the bark removed with it should be inserted in the cleft in the stock and care taken to see that the cambium of bud and stock are in contact. The bark of the stock should be tied securely about the bud with two or three turns of twine or waxed cotton, but the bud itself must not be covered, and as soon as it has been incorporated with the stock, which should occur in about ten days, the wrappings must be removed. The bud remains dormant until spring, and as soon as growth begins, the part of the stock above the bud should be removed and the latter left to form the new plant. In budding young plants the bud is inserted about two inches above the soil; in larger specimens it may be inserted anywhere on the young growth. By selecting buds of different varieties one may have several kinds of fruit on the same tree. While budding, neither bud nor stock should be allowed to become dry. It is also well to bud on the north side of the stock, where the bud will not be exposed to the sun. Several other forms of budding are in use, but the principle is the same in all. In *ring*, *flute*, or *annular* budding a piece of bark extending part way around the stock is removed

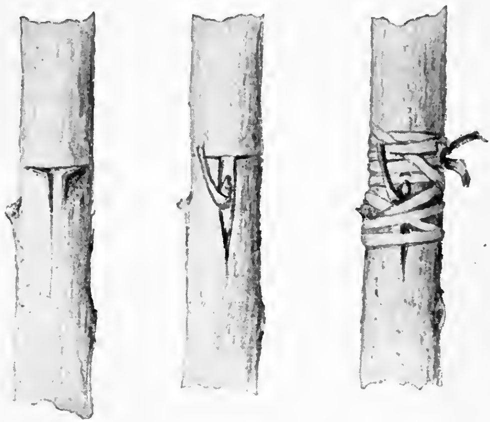

Fig. 140. Three stages in the operation of budding In the figure on the right the work has been completed

and a similar piece of bark with a bud from another plant is fitted in. This method is most frequently used in budding thick-barked trees such as hickory and magnolia, the work being performed in early spring. *Prong budding* is really a form of grafting in which a short twig is treated as a bud.

Grafting. Grafting is in many respects like budding, since it consists in transferring a part of one plant to another, but in the present case a small twig, called a *cion*, or *graft*, is used instead of a bud. The cions are collected and stored in autumn exactly like hardwood cuttings, and the only practical difference between them is that the cutting is designed to draw part of its nourishment from the soil through its own roots, while the cion is intended to become a part of another plant with no roots of its own. The essential thing in all grafting is to see that the cambium of stock and cion meet, and that the point where they join is protected by grafting wax until the two have grown together. Grafting must be done in late winter or early spring while both stock and cion are dormant. As in budding, cion and stock must be from nearly allied species. Sour apples or pears may grow on sweet-apple stock and peaches on plum stock, but widely separated species can seldom, if ever, be made to unite. A single tree may be made to bear half a hundred different varieties of apples by grafting, and each will come true to its nature. In species with diœcious flowers grafting may be employed to make sterile forms fertile.

Different forms of grafting. Two principal forms of grafting may be distinguished: *cleft grafting* used in working over old trees; and *whip grafting*, the method commonly employed with small or young stock. In *cleft grafting*, a branch about two inches thick is sawed off, the stump is split with a chisel or knife, and the base of the cion, cut to slender wedge shape, is inserted in the cleft. Usually two cions are used, one on each side of the cleft, and to insure that the cambiums of

stock and cion shall meet, the cions are often made to diverge slightly. The cleft is then covered thoroughly with grafting wax, to keep out insects and decay until the wound heals. *Crown grafting* is like cleft grafting except that it is used in renewing the top of shrubs and vines that have been cut off at the surface of the soil. Cleft grafting is rarely used except in attempts to give old trees a new lease of life. For all ordinary work *whip grafting* is employed. Numerous forms of this are in use, but they differ for the most part only in the way cion and stock are joined. In the form called *saddle grafting* the top of the stock is cut in wedge shape and the cion is cut with a deep notch to match it. In *splice grafting* a long tapering cut from one side of the stock to the other fits a similar cut on the cion. *Tongue grafting* is an improved form of splice grafting, in which a longitudinal cut is made about one third of the distance from the tip of the cut in both cion and stock. These are then wedged together, forming a close union that is not readily injured by the weather. In *veneer grafting* a notch is made through the bark of the stock, and the base of the cion, cut to fit, is inserted. *Bridge grafting* is sometimes employed to repair injuries to the bark of large trees. The edges of the wound are first straightened up and several twigs of the same species are obtained, their ends cut wedge shape

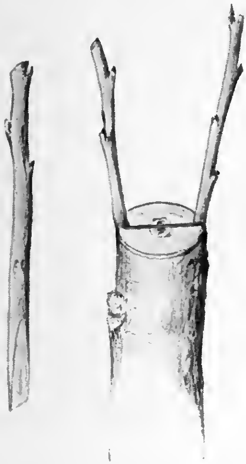

FIG. 141. Cleft grafting
This method is used on large specimens

FIG. 142. Three forms of whip grafting

and inserted into the bark above and below the wound. In this way the sap is carried past the injury until the tree can cover it with bark. In *root grafting* the cion is joined to a piece of root. This is regarded as one of the best forms of grafting, since the cion may also put out roots and help to nourish the plant; in fact, this hardly differs from growing a plant from a hardwood cutting. In all the forms of whip grafting, stock and cion are carefully bound together with waxed cotton twine or grafting wax until a perfect union occurs. Root grafts, being underground, do not need this protection.

Fig. 143. Tongue grafting
Illustration of one of the best methods

Although herbaceous plants are rarely grafted, it can be accomplished. Grafts between the tomato and the potato, the morning-glory and the sweet potato, the artichoke and the sunflower, are now and then reported. In grafting herbaceous plants veneer grafting is the best form to use, but in this case the cut in the stock should be made deeper than for hard-wooded plants. Even fruits have been grafted when half grown. The grafting of soft-wooded plants is most successful when carried on under glass, where the conditions of temperature and moisture can be controlled.

Inarching. Inarching is a form of grafting in which cion and stock are united while both are still joined to their own roots. In this, one stem is bent over toward the other, the cambium

of each exposed, and the two stems bound together until a union is formed. The top of the stock is now cut off and the cion cut away from its roots. In the same way a small plant in a pot may be inarched to the branches of a large tree. In the forest one may often see examples of natural inarching where two plants have come into contact.

Grafting wax. To make grafting wax, take four parts of rosin, two parts of beeswax, and one part of tallow or linseed oil, and melt all together. When thoroughly mixed pour into cold water, and, when cool enough, work it like molasses candy until it assumes a light straw color. Make into rolls and wrap in waxed paper until wanted. If a harder wax is desired, the amount of rosin or beeswax may be increased. The hands should be greased with tallow before attempting to work the wax. Waxed twine for tying buds and grafts may be prepared by putting a ball of No. 18 knitting cotton in the kettle of melted wax for a few minutes.

Effect of stock on cion. Usually the nature of the stock has little effect on the cion, but cases are known in which apples grafted on wild-crab stock have produced more acid fruits, while late apples may ripen earlier as a result of grafting them on stocks of earlier varieties. Certain species may be dwarfed by grafting them on slow-growing stock, and the time of fruiting may often be greatly modified by the kind of stock and cion selected. Apples usually grow for ten or more years before fruiting, but a young seedling grafted on old stock may fruit in a year or two. On the other hand, a twig from an old tree grafted upon a seedling may grow for years before producing fruit. Many French grapes are grafted on American stocks, which are more resistant to the dreaded plant louse, *Phylloxera*, which infests the roots. Rarely the union of graft and stock may produce twigs with characters that appear intermediate between the two. Such specimens are known as *graft hybrids.*

PRACTICAL EXERCISES

1. From pictures, from dried specimens, and from plants in the garden, learn to recognize the various forms by which plants are propagated vegetatively.

2. In the school garden examine all the crops grown, with a view to propagating them. Which are most susceptible to treatment in this way, the crop plants or the permanent species? Can you discover the reason for the difference?

3. In the borders find plants to illustrate propagation by each of the methods given in this book. Make a list of them.

4. Make softwood cuttings and root them in the hotbed or cold frame.

5. In autumn make hardwood cuttings of all the types mentioned, and store as required. In spring, if cuttings of this kind have been left by a former class, try rooting them in the cold frame, in the hot bed, or in the open.

6. Layer any vine that may be convenient in the school garden. Try layering currant bushes for planting later at home.

7. If cions are at hand in time to graft, make several kinds of whip grafts. If materials for practical grafting are not at hand, make grafts of any twigs for practice.

8. Plant seeds of different trees in the experiment plots, for use of the next class in budding and grafting.

9. Bud a convenient plum or peach tree. Each class should plant seeds to produce young trees for this purpose for the next class. If your budding operation is successful, take the plant home and set it out.

10. If a large peach or plum tree is available, set in it buds from other trees bearing different kinds of the same fruit. One may have specimens of all the kinds in the neighborhood by this method.

11. Make grafting wax and carry some home for use in your own grounds.

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157. The Propagation of Plants.
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CHAPTER XIV

DECORATIVE PLANTING

Purpose. The purpose of decorative planting is to add to the comfort and attractiveness of our surroundings by planting those plants that are conspicuous either for the beauty of their flowers, the color and cutting of their foliage, or the symmetry of their form, thus making homes of houses and parks of wildernesses. Not all planting of this kind, however, can be called decorative. To be entitled to the name it must proceed along definite lines, with a preconceived design in mind; for unless a definite plan is adhered to, the result is likely to be lacking in harmony and coherence. In planting the home grounds the aim should be to set off the house to the best advantage, emphasizing the good points and concealing the poor ones; in short, to make a picture, with the house as the central figure and the borders as the frame.

Lawn making. Few things add more to the beauty of the home grounds than a broad expanse of well-kept lawn, but this can be produced only by proper care in the making. If the old lawn is unsatisfactory, it is best to spade or plow it up in late fall or early spring and start a new one. The first step in lawn making is to see that the land is properly drained. If it is not, this should be taken care of by one or more lines of tile drain. After digging, the soil should be very thoroughly worked over until it is well pulverized and carefully leveled. If the soil is lacking in fertility, a quantity of well-rotted manure should be worked into it, or other fertilizers applied. Small lawns should be perfectly level unless the residence is on sloping ground. In the latter case it is much

better to have the lawn slope gently away from the house than to cut it up by banks and terraces, since every division, whether by path or terrace, tends to make it look smaller than it really is. If terraces cannot be avoided, they are best placed near the house, where they may become, in a measure, a part of the building, or else as far away as possible — at the street line or on the borders of the property. On no account should the center of the small lawn be lower than the borders, since a concave surface tends to make distances appear shorter and the lawn, in consequence, smaller. A slightly convex surface, on the other hand, gives a more spacious look to the property, and in large lawns the center is often raised slightly to prevent it from looking hollow at this point. Since the grasses are cool-weather plants and flag during the summer, it is best to seed the lawn in late fall or early spring, so that the plants may become established before the hot weather sets in. If seeded later, care should be taken that the young plants do

Fig. 144. Hickory Creek at Joliet, Illinois

An illustration of the way Nature arranges her trees and shrubs

not suffer from drought. Bare spots in an old lawn can be loosened with a rake and reseeded at any time. Occasionally when a lawn is wanted quickly, or the soil on a sloping bank is to be retained, the whole area may be sodded. For this work sods from an old pasture are best, since they consist of only the most resistant grasses and are fairly free from weeds. Ground to be sodded should be prepared as carefully as for seeding. After the sods are laid they should be thoroughly

Fig. 145. Forest and stream illustrating Nature's method of planting

watered and then beaten into place with the back of a spade or rolled with a heavy roller. It is difficult to make grass grow in deep shade, under evergreen trees and the like, and some other ground cover is often used. Among the best plants for this purpose are the periwinkle or myrtle, lily of the valley, and moneywort.

Paths and lawn planting. In small lawns the paths should be straight and direct, but in larger areas they may curve, especially if the surface of the land is uneven. Every path or drive crossing the lawn makes it look smaller and adds to the care that must be bestowed upon it; no unnecessary walk,

therefore, should be permitted. Paths and drives are often sunk a few inches below the surface of the lawn, which thus conceals or renders them less conspicuous and contributes to the appearance of spaciousness so desirable to maintain. For the same reason the center of the lawn should be kept open and free from flower beds, shrubs, and trees. In large grounds, and in strictly formal planting, such things may be allowed, but they are out of place on the home grounds. The kettles,

Photograph by Wagner Park Conservatories, Sidney, Ohio

Fig. 146. A corner planted in the natural style

vases, sections of sewer pipe, paint buckets, and tubs filled with flowers that are often seen on lawns are in bad taste and should not be tolerated. Such objects, when used at all, should be restricted to formal planting. Occasionally it is desired to separate the lawn from adjoining fields without seeming to do so. This can be accomplished by digging a ditch deep enough to conceal a fence placed in the bottom. The side of the ditch nearer the house may be slightly raised, thus hiding the ditch and making the lawn appear to merge into the fields beyond.

Care of the lawn. The care of a well-established lawn consists in cutting, fertilizing, watering, and rolling it. It should be cut frequently, and if this is done, the clippings may be left to form a mulch for the grass roots and to prevent the seeds of weeds from becoming established. Cutting the lawn is most easily done in the morning, since at this time the cells of the grass are distended with water and therefore more brittle. The lawn should be watered only when in need of it, and then it should be thoroughly soaked. An occasional heavy watering is much to be preferred to the daily sprinkling that is often given it. The latter causes the surface to bake, and makes the grass more shallow-rooted and more easily burned up in summer. Commercial fertilizers are best for the lawn; the winter dressing of stable manure so often applied is not only unsightly and unsanitary, but it may introduce many noxious weeds from seeds mixed with the manure. Late in the season the grass may be allowed to grow longer and form a cover for the roots during winter. In early spring the lawn should be carefully raked and then rolled with a heavy roller, to settle back into place any grass roots that may have been lifted by the frost.

The border. The shrubs and flowering plants that so often find a place on the lawn are better located on its borders. Here they add a distinct note to the ornamentation of the grounds. Shrubs and flower beds scattered over the lawn give it a spotty appearance, out of all harmony with the rest of the picture. Nor should flowering plants designed for cutting be allowed anywhere on the lawn or in the borders. They are best restricted to some part of the garden where the loss of their blossoms will not be so much noticed. The flowering plants in the borders should be allowed to finish their season of bloom undisturbed. In planting the border it should be remembered that Nature always works in curves, and if an appearance of naturalness is to be produced, straight lines

should be avoided. The line where lawn and border meet should be a series of graceful curves, and the shrubs and herbaceous plants should be arranged in irregular groups. In this, one can have no better guide than Nature herself, and a visit to the bushy margins of an old field or the edge of a woodland will be of great assistance to the observant student. In making the outline of the border a stout rope or the garden hose may be used to get the desired curved effect, and the line can then be marked out along this.

Arrangement of the plants. Trees, shrubs, vines, and herbaceous plants may all find appropriate locations in the border.

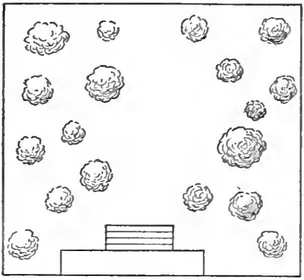

FIG. 147. The wrong way to plant shrubs on a lawn

Such an arrangement makes a spotty appearance

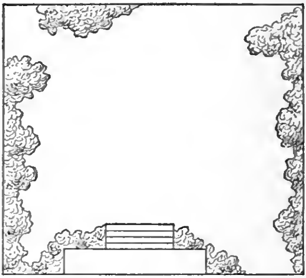

FIG. 148. The correct way to plant a lawn

Shrubs arranged on the borders; center of the lawn kept open

The trees and shrubs are used to form the framework of the plan, and the less rugged and assertive plants are grouped about them. In arranging them care must be taken that the taller specimens do not shut out the view from the windows and veranda of the house. In large grounds, especially, vistas to distant points in many directions should be maintained. Grounds that have been planted for some time often have these views obscured by an undue growth of shrubbery unless it is properly trimmed. On the other hand, undesirable views or unsightly objects can be entirely concealed from

view by screens of shrubbery planted for the purpose. A profusion of low-growing shrubs should be used to conceal the foundations of the house, and vines may be trained over walls and pillars, thus carrying the green of the lawn upward and making the house appear more a part of the landscape. Shrubs should rarely be planted singly. Their beauty is greatly enhanced if several are set to form an irregular group, but care must be taken to allow for future growth, else they will soon begin to crowd one another and fail of their best development. Not only should the line where lawn and border meet be irregular, but the sky line should partake of the same character. This is brought about by alternating groups of tall and shorter shrubs and trees. It is desirable, also, to bring some of the shrubs out toward the margin of the lawn, forming recesses or bays between them in which herbaceous plants may be grown. Shrubs may be planted on the concave side of all curves in paths and drives, thus seeming to give a reason for the curve as well as adding to the spacious appearance of the grounds by preventing all parts being seen at once. At the angles where paths intersect, and where "short cuts" are likely to be made, it is well to plant thorny shrubs like the barberry, locust, and prickly ash. Such plantings are also frequently made in the

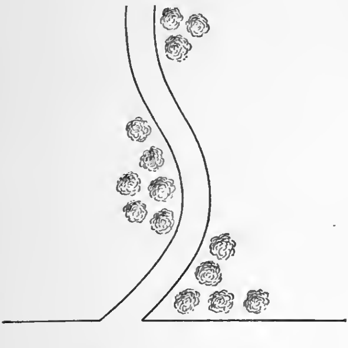

Fig. 149. Shrubs in the curves of a drive

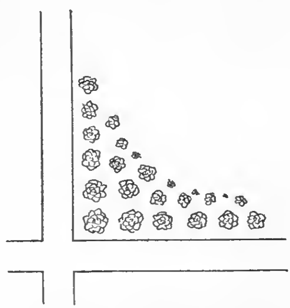

Fig. 150. A corner planting

front of shrubbery where it borders the street, to prevent the encroachment of the public.

Shrubs for winter effects. The best-planted grounds are not designed solely for their beauty in summer. A proper selection of shrubbery will not only look well in summer but will add numerous pleasing tints to the winter landscape and brighten the borders with the colors of a milder season. In this class are the bright scarlets and purples of the dogwoods and some willows and wild roses, the yellow and gray of willow and beech, the green of euonymus and cat brier, and the white of the birch and buttonwood. At the leafless season, also, the form of the plant is thrown into strong relief, and various species may be planted for the picturesque note they add to the winter landscape. Among common species desirable for this purpose are the hawthorns, the river birch, black gum, and Lombardy poplar. Numerous shrubs produce attractive fruits that persist far into the winter, supplying food for the winter birds and adding a touch of color to the thickets. The winterberry, greenbrier, bittersweet, burning bush, and the roses are good for this purpose.

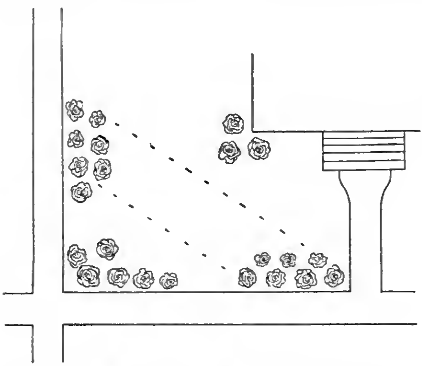

FIG. 151. Method of planting a corner lot, to prevent paths being made across it

Naming the shrubs and trees. Shrubs and trees are among the most permanent of living things and often outlast the works of man himself. It is desirable, therefore, that the student become acquainted with those commonly planted, either by identifying them by the use of a botanical manual, which is much the better way, or by visiting named collections

in parks, botanical gardens, and private grounds. The more permanent of the herbaceous perennials may also be identified. Complete lists of these, with notes on the qualities that make them desirable for planting, may be obtained from the nearest nursery company. A large number of the more desirable are natives of our own fields and woods, and the person interested in decorating his grounds will find many of them ready to his hand in the nearest woodland or thicket. Few exotic species surpass our native elders, sumacs, dogwoods, viburnums, wild crabs, currants, and gooseberries for decorative planting. Trees and shrubs with variegated foliage are usually less hardy than those with green leaves and are seldom satisfactory in the home grounds.

Fig. 152. An artificial pond planted with lotus and water lilies

Herbaceous plants. Herbaceous plants may be considered in two groups, the annuals and the perennials. The annuals are frequently desirable for quickly covering bare spaces and for giving an abundance of bloom, but they require to be planted anew each year, and for most purposes perennials are more desirable. Some of the most showy flowers, however, are annuals. We could ill spare such species as morning-glory, four-o'clock, nicotiana, nasturtium, sweet pea, petunia, aster, cosmos, salvia, and verbena, but the best place for most of them is in the flower garden where their beauty may be admired and the flowers removed without injuring the appearance of the

surroundings. Many of the perennial species are desirable for the flowers they produce, but when these are needed for cutting, they too should be planted in the flower garden and not in the border. Among the better-known perennials are the lilies, columbines, irises, phloxes, peonies, sunflowers, bellworts, bleeding hearts, and pinks. Left to themselves, the herbaceous perennials soon form large clumps, which may often be divided and used to make further plantings.

Photograph by O. L. Jordan

Fig. 153. An old planting in which the border has all the appearance of a natural growth

Arrangement of herbaceous perennials. In planting the herbaceous perennials the general rules for planting shrubbery may be followed, especially those regarding mass planting and the avoidance of straight lines. Since they are always planted for the decorative effect of their flowers, they should be placed in front of the shrubbery, which thus forms a natural background and renders the flowers more conspicuous. Tall plants should be placed in the rear and successively smaller ones

should carry the belt of verdure down to meet the lawn. A general group of perennials may consist of several sorts intermixed, and if care is taken to choose species that bloom at different seasons, a succession of flowers may be had from the same spot during the summer. In mixed plantings, where two kinds of flowers are to bloom at once, or where adjacent plantings come into bloom at the same time, one must avoid the planting together of inharmonious colors, such as magenta and scarlet, or purple and blue. White flowers may be used to separate warring colors and also to serve as a foil for all others. Both purple and blue flowers add a sense of distance to the view, and, if planted in bays in the shrubbery, appear to increase the size of the garden. Yellow and red flowers have the opposite effect. By planting them on jutting points they add to the apparent depth of the bays.

Hedges. In some cases it is desirable to divide two plots of ground, or to set off the home grounds from the street, by means of a hedge. For repelling intruders or keeping stock within bounds, the hedge is made of some thorny material, such as Osage orange, honey locust, barberry, or buckthorn. About dwellings it is more usual to plant privet, lilac, box, or some of the evergreens like arbor vitæ and hemlock. Hedge plants are set thickly in straight lines and are trimmed into shape annually during the summer season. The words "hedge" and "edge" are obviously of similar derivation, and edgings are naturally lines of small plants like small hedges set along the borders of other plantings. Pansies, alyssum, lobelias, and many other low-growing species are used for this purpose.

Bulbs. All plants propagated by thickened underground parts are called bulbs by the florist and general gardener, and, for the purposes of planting, no other distinction need be made. The chief value that attaches to bulbs is found in the fact that the flowers are usually showy, and, being formed in the preceding summer, are practically certain to appear when

the bulbs are properly planted, pushing upward almost as soon as the snow is gone and blooming at a time when flowers of any kind are rare. In addition to the spring flowering bulbs there are a few that bloom in summer. Summer flowering species are nearly always tender and have to be dug up and kept from the cold during the winter. The gladiolus and tuberose belong to this class. The spring flowering bulbs are not only hardy but they have to be planted in autumn in time to make root growth if they are to bloom the following spring. During summer they may be dug up and stored in a cool dry place, or they may be allowed to remain in the soil and annuals planted over them. Many low-growing species may be naturalized on the lawn and will bloom before the grass is high enough to require cutting. If not cut too closely in mowing, they will continue to bloom from year to year. Taller species, such as the daffodil and narcissus, are occasionally naturalized along the margin of streams and the edges of woodlands, where they thrive as well as our native species. In planting the spring flowering bulbs, a well-drained spot, protected on the north and west, should be selected. They may be planted in masses or formal groups, and as soon as the ground is frozen should be covered with several inches of coarse straw, leaves, or other litter. In spring the mulch should not be removed until the growing plants require it; otherwise they may be injured by the cold. In the public parks and other large grounds bulbs are frequently arranged in geometrical and other designs.

Carpet bedding. This is the term applied to a form of planting in which plants with bright-colored foliage are arranged in formal designs and kept trimmed to an even surface, giving an effect not unlike a carpet or rug. *Ribbon bedding* is much like this, since it consists in setting plants in long, straight rows. This kind of planting may be used along walks and in other situations where straight lines prevail, but is not adapted to plantings in the natural style.

Formal planting. The rules for planting given in this book are for that style of gardening known as the *English* or *natural* style. It is patterned closely after nature and is the one most in use in the United States and Great Britain. A more formal method, known as the *Italian* or *geometrical* style, once in great vogue and still extensively used in parks and large estates, consists in making all planting on geometrical lines. Here clipped shrubs, plants in vases, sundials, pergolas, angular beds, balustrades, terraces, arbors, fountains, statuary, weeping trees, carpet bedding, and straight lines find an appropriate

Photograph from Wagner Park Conservatories, Sidney, Ohio

FIG. 154. A formal garden

Note how this planting harmonizes with the style of architecture

use, and when thus assembled have an attractiveness that is beyond question. Such planting, however, is out of place in the small lawn unless the entire area is treated in the same style.

Transplanting shrubs and trees. As a rule, shrubs and trees cannot be transplanted with safety when in full leaf. They are usually moved in autumn after the leaves have fallen or in spring before the buds have pushed forth, but if care is taken to keep the plants from drying out, they may be moved in spring until the leaves are nearly full grown. Nurserymen commonly prolong the planting season by digging up their stock in autumn and keeping it in cold storage until wanted.

Specimens may thus be had in a dormant condition long after the same kinds of plants in the field have produced their leaves. In transplanting trees and shrubs the rules that govern the transplanting of garden plants in general may be observed. If many of the large roots have been severed in digging, the top of the specimen must be cut back to balance the loss and

Photograph by Wagner Park Conservatories, Sidney, Ohio

FIG. 155. The natural style of planting applied to the home grounds

prevent too great transpiration. In doing this it is better to remove weak branches and superfluous twigs rather than to cut off the top or main branches and thus destroy the natural shape of the specimen. In the case of shrubs, when it may be desirable to retain as many branches as possible, the leaves only may be removed. The removal of the leaves is also practiced in moving shrubs in early autumn before the leaves have fallen. The roots should never be allowed to become

dry while transplanting, and, before the specimen is set, all broken and bruised roots should be cut back to the sound wood with a sharp clean cut. Specimens should be set slightly deeper than they stood originally, and it is well to have the same side toward the north. The hole in which the plant is to be set should always be large enough to allow the roots to spread out naturally. This hole is sometimes made by exploding a small charge of dynamite, which loosens the subsoil and makes it easy for the new roots to penetrate it. The best soil should be used for filling about the roots and should be well firmed about them. If the plant is set in poor soil, enough good soil should be procured elsewhere to fill up the hole. When the hole is half filled, the plant may be gently worked up and down to settle the earth about the roots, or water may be thrown into the hole for the same purpose. No air spaces about the roots should be permitted.

Transplanting herbaceous perennials. As with the woody plants, the best time to transplant herbaceous perennials is in fall or spring, but owing to the fact that these plants are smaller and more easily handled, they may be moved at any time if a few simple rules are observed. In the case of wild plants, many of which are among our most ornamental species, the rule most frequently followed is, "Transplant when you find them." By using care in the digging, keeping the specimen moist, and protecting from the sun until established in the new locality, one can move almost any specimen without loss even when in bloom.

Mulching and heeling in. Newly set herbaceous plants are benefited by a light mulch over their roots, which keeps the moisture from evaporating and the soil from baking. Plants set in autumn should be more heavily mulched as soon as the ground is frozen, and this should not be removed until the frost is out of the ground in spring. Such a mulch prevents the heaving due to the alternate thawing and freezing of the

ground, and is especially desirable in the case of plants in exposed places. More plants are killed annually by having their roots broken when heaved by the frost than by the cold of winter itself. It often happens that more plants are dug than can properly be planted at one time, and in such cases the surplus is *heeled in* until they can be planted. In heeling in, a trench is dug deep enough to receive the roots, and the plants are placed within this in such a way that the tops rest on the earth. Soil is then thrown on the roots in widening the trench, and then another layer of plants with tops overlapping the first is put in, and so on. Plants are frequently heeled in over winter. In such cases the roots should be heavily mulched as soon as the ground is frozen, but if the tops are mulched, it may form a retreat for mice that may damage the bark or buds. Plants should always be heeled in in a light, well-drained spot.

Treatment of woodlands. The ever-increasing demand for wood in various industries has greatly diminished the immense forests that once covered our country, and the remnant is fast disappearing. All this greatly enhances the value of the timber still standing. In some regions trees are already treated as farm crops, and everywhere there is being manifested a desire to manage the woodlands so that the greatest amount of timber may be obtained from the area they cover. Formerly it was the custom to cut down the entire stand of trees in lumbering and to clear the ground, but at present in all forests where conservative methods are practiced, only the marketable timber is removed and the remainder is left to produce a new crop. The forests may thus be made to yield perennial supplies. Properly cared for, most forests will continue to reproduce themselves. When this does not occur naturally, it is usual to plant young trees of the desired variety. In all broken country there are many areas too steep or too infertile to produce ordinary crops, but on which excellent

timber can be grown. Many of these are being reforested by planting with young trees. It is probable that in time all such regions will be again covered with forest. At present a wood lot managed as a growing crop of fence posts, railway ties, and telegraph poles may be made to yield quite as much as the same area planted to annual crops, and with no greater amount of labor or capital spent upon it. The steadily advancing prices of all kinds of timber make it clear that in future a much greater revenue may be derived from such wood lots than from the ordinary crops.

Enemies of the forest. The three greatest dangers that threaten the forest, aside from wasteful cutting, are fires, insects, and plant diseases. To reduce these to a minimum, it is desirable that all dead and dying trees and underbrush that might furnish food for the fire or a lurking place for insects and fungi be removed. Vigorous trees are least susceptible to insect and fungous attacks, and only the best trees should be left to grow. The misshapen specimens and others that crowd the good trees for light and room should be removed. In the forest, trees whose timber is of no value are as much weeds as are mustard and pigweed in a field of grain. In extensive forests, where injury from fires is most likely to occur, the ground is divided into sections by fire lanes — broad, cleared strips wide enough to confine the forest fire, once started, to a single section. The custom of allowing cattle to graze in the forest is extremely harmful, since the young trees are destroyed and the perpetuation of the forest prevented.

Quite aside from their value as a source of timber and fuel, forests are of great benefit in preventing floods by delaying the run-off from rain and melting snow. In forested areas much of this moisture sinks into the soil, to reappear later in springs which keep the small streams from drying up in summer.

PRACTICAL EXERCISES

1. Make a planting plan for a city lot of average size on a scale of $\frac{1}{4}$ or $\frac{1}{8}$ in. to the foot, indicating on it the house, walks, and drives, and the location and nature of the planting.

2. From a catalogue of decorative plants, to be had of any nurseryman for the asking, select and list the species suggested for planting your plan.

3. With such suggestions as seem desirable for improving the planting, make a similar plan of your home grounds or of the school grounds.

4. Visit parks, cemeteries, and private grounds for studies in good and bad planting effects.

5. If there are Italian, or formal, and Japanese gardens within reach, visit them and compare with the natural style of planting.

6. Make a planting plan, drawn to scale, of some small park in the vicinity, or make a planting plan for turning some near-by vacant space into a park.

7. Select desirable plants and plant a section of the school-garden border.

8. On Arbor Day plant one or more trees or shrubs on the school grounds, in the school garden, or in your home grounds.

9. At the beginning of winter mulch all plants in the school garden that are likely to be harmed by the cold. Do the same for your own grounds.

10. Make one or more trips to a public park or large private estate, and list all the shrubs found in bloom. Make a similar list of all the perennials.

11. By the use of a good botanical manual name all the shrubs and perennials as they bloom in the school garden and near-by fields during the time devoted to this course.

12. Remove to the school-garden borders for observation all abnormal plants encountered, such as four-leaved clovers, albinos, fasciated stems, and the like.

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Waugh, "Landscape Gardening."

CHAPTER XV

PRUNING

Purpose of pruning. The object of pruning is to repair injuries, promote the proper growth of the specimens, and secure more shapely, healthy, and fruitful plants. Many species grow so luxuriantly that they require an annual trimming to keep them within bounds. Others, again, may produce a crown of foliage so dense that sufficient light and air do not penetrate it; in consequence of this few flower buds are formed, and what fruit is produced is pale in color and poorly flavored. Such a specimen is benefited by pruning. Although woody species are the ones usually pruned, a few herbaceous plants commonly receive the same treatment, especially tomatoes, tobacco, okra, and various garden flowers. Many woody plants are self-pruning and annually cut off many of their

Photograph by H. L. Hollister Land Co.

FIG. 156. Apple blossoms

Showing the good results of proper pruning

young twigs. The habit of cutting off the useless flowers after blooming may also be regarded as a form of self-pruning, as is the casting of the leaves in autumn. It is commonly supposed that only flowers that fail to be pollinated are cut off by the plant, but many young fruits are also severed from the branches, otherwise the plant could not make sufficient food for all, and even if it could, the load would be more than it could bear. The advantages to be derived from thinning the fruit on trees heavily loaded is obvious.

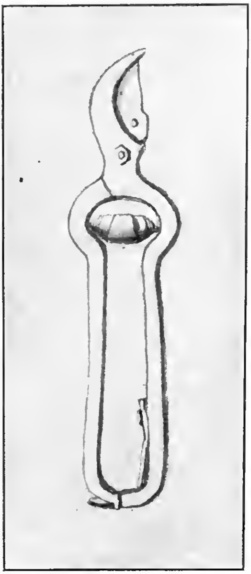


Fig. 157. A common form of pruning shears

Time to prune. An old rule for pruning is, "Prune when the knife is sharp," indicating that when a plant needs pruning one time is as good as another, but such a rule has many exceptions. The time for pruning any plant depends somewhat upon the time at which it produces its flowers. Plants that form their flower buds in autumn should not be pruned in winter, as this would remove the embryo flowers and fruits. Such plants should be pruned in spring and summer, shortly after they have fruited and before new flower buds have been formed. On the other hand, many plants produce their flowers on the new wood, that is, on twigs produced from winter buds. These may be pruned in winter, since new and vigorous wood will usually be more floriferous than older twigs. In general, winter pruning increases the amount of wood formed and summer pruning induces flowering. Summer pruning has the advantage over winter pruning in that one may then see how the crown of foliage is displayed and may more readily remove branches that shade others. Moreover, the cambium,

active at this season, soon covers the wound with a protective layer of bark. One should be careful not to overprune; a little pruning yearly is much better than more at longer intervals.

Pruning implements. A good sharp knife is a most efficient pruning instrument, and the intelligent horticulturist seldom needs anything else. Pruning shears with stout blades may take the place of the knife, but when shrubbery has been allowed to go for some time, large branches may require the use of a saw. There are various kinds of pruning shears and saws on the market, some forms of the latter having teeth on both sides of the blade.

FIG. 158. An apple tree

An example of improper pruning. The tree has been allowed to grow so high that it is difficult to gather the fruit

Methods of pruning. There are several rules that may be observed in pruning any shrub or tree. It is always proper to remove branches that shade others as well as those that grow toward the interior of the crown. These latter are soon cut off from the light by the growth of the outside branches, and, if not removed, would soon die anyway. Branches that have grown too rapidly for the symmetry of the plant may be cut back, but in all cases where part of a twig is removed care must be taken to cut above a bud facing outward, else the new growth is likely to grow toward the

center. In selecting the branches to remain, every endeavor should be made to have no gaps in the crown of foliage. There should be enough branches to fill it out on all sides. In shaping young fruit trees and the like, the branches should not be allowed to spring from a common point, and all forks should be avoided. Looking down upon the specimen and imagining a circle with the trunk of the plant in the center, endeavor to train it in such a way that from three to five main branches radiate out at equal distances and form the framework of a well-balanced crown. In setting young fruit trees they are sometimes pruned to mere whips and a new head developed from the fresh twigs that will spring forth. Orchard trees are usually headed low to facilitate gathering the fruit.

Making the cut. In removing branches all cuts should be made close to the stem, and no stubs left to harbor insects and the germs of disease. In removing very large limbs there is always danger that they may fall by their own weight and thus tear down the bark and wood of the main stem before the cut is complete. This may be avoided by first making a cut part way through the branch on the underside and a foot or more from the trunk. A cut from above meeting this or a little beyond it will sever the limb, after which the stub may be sawed off close to the trunk. If the branch removed is more than an inch in diameter, the wound should be immediately covered with a coat of paint or grafting wax to keep out injury from the weather, bacteria, and insects. Scars left by the removal of smaller branches may be disregarded, as the tree will soon cover them with bark.

Specimens needing little pruning. The evergreen trees should never be pruned. When properly grown the branches radiate on all sides from the ground up, and the trees lose much of their beauty when trimmed like other trees. An evergreen tree, once deprived of its lower branches, rarely renews them. Shade trees seldom require pruning except to remove dead

branches and to repair damage by storm. Many shrubs also, among which are lilacs, deutzias, spiræas, and forsythias, do well without much pruning. The plants most frequently pruned are those grown for their fruit, and the object in pruning is to force them to bear more and better crops by the production of new wood upon which the fruits are borne. In

Photograph by H. L. Hollister Land Co.

Fig. 159. Cherry trees in bloom in an irrigated orchard

temperate regions flowers seldom appear on wood that is more than two years old. In the tropics flowers often appear on the large branches or even the trunks of trees. In the hands of the skilled gardener all the flowering shrubs may be induced to bear the maximum number of flowers by judicious pruning.

Pruning special crops. Some plants produce but one crop of flowers and fruits on a branch, no matter how long it may remain on the plant after fruiting, and such branches are as

well removed as not. Other species form certain short branches, called fruit spurs, that bear many successive crops. It is necessary, therefore, to know how each specimen fruits before it can be pruned intelligently. The *raspberry* and *blackberry* always fruit on canes grown the previous year and do not bear fruit on these canes a second time. As soon, therefore, as the fruiting season is over, the old canes should be removed to make room for the new ones. When the latter have reached a height of two or three feet, the tips are also removed, which causes side branches to form and increases the wood upon which the fruit is borne. In *grapes* the fruit is borne upon the new wood, that is, upon wood produced the same year as the fruit. In training these plants it is customary to allow one or more main stems to grow, and these are trained upon posts, wires, or trellises. From each joint of these stems a branch arises which bears fruit. After the crop is gathered these young branches are cut back nearly to the main stem, only mere stubs with two or three buds being left. The following season, when these buds begin to grow, the best are selected to form the fruiting branches for that year. Grapes should be pruned when perfectly dormant. If pruned later than February, they are likely to bleed and to be harmed thereby. *Apples*, *pears*, and *cherries* form short fruit spurs on the old wood. These bear fruit year after year, and care should be taken not to injure them when pruning or

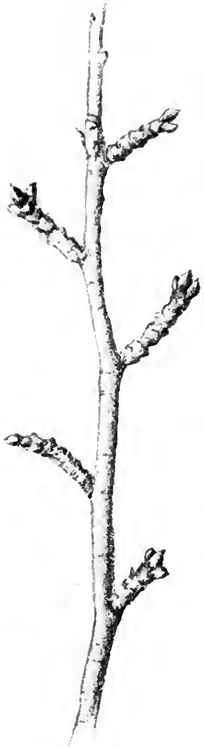


Fig. 160. Fruit spurs on the second-year wood of cherry which may bear several crops

when gathering the fruit. Shortening the new growth of these trees induces the formation of more fruit spurs. The *peach* fruits on wood one year old; that is, branches produced one summer should fruit the next. Since checking the growth favors fruiting, cutting back part of the new growth late in summer influences the formation of flower buds. The peach is a luxuriant and rapid grower, and, if allowed to go unpruned, is likely to produce more wood than fruit. *Currants* produce fruit on both the old and new wood, but wood more than three years old is considered unprofitable and may be removed. The new growth tends to produce more fruit buds if it is pinched back to leave from two to six buds on each twig.

Fig. 161. Two-year-old twig of the peach showing three pedicels, or stalks, that produced fruit and will not bear again

Thinning. Thinning, or the removal of some of the fruit when the tree is overloaded, is a form of pruning. Several advantages are gained by thinning. If all the fruit is left on the tree, the load may be so great as to break the branches, while the effort to produce so great a crop results in a quantity of undersized, flavorless specimens. It is much better to

Photograph by H. L. Hollister Land Co.

FIG. 162. Peaches growing on wood of the preceding year

Photograph by H. L. Hollister Land Co.

FIG. 163. An overloaded branch of a plum tree

The fruit should be thinned by removing all small or imperfect specimens

remove some of the fruit than to endeavor to save it all by propping up the limbs. Overbearing may also weaken the plant so much as to prevent all fruit bearing the following season. In thinning, the effort should be made to have the

Photograph by H. L. Hollister Land Co.

Fig. 164. Rome Beauty apples

Note that the fruit is produced from short spurs on the old wood

fruit uniformly scattered over the tree. The inferior and poorly placed specimens are of course the ones to be removed. Wormy and defective fruits may often be brought down by gently shaking the tree occasionally.

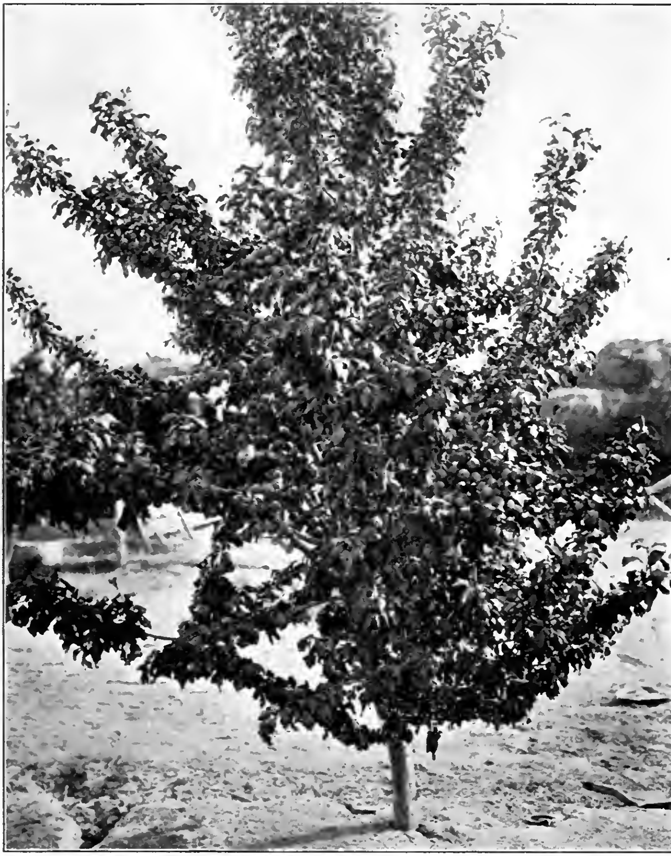
Heading in. Many species, especially when young, make such luxuriant growth that some of it needs to be removed in order that the rest may ripen into strong wood. Removal of

Photograph by H. L. Hollister Land Co.

Fig. 165. A heavily loaded branch of currants

the excess growth is called *heading in.* The peach, pear, crab, and poplar are among those most frequently headed in, but any rank-growing species may need it. When nearly all the

crown is removed, by cutting off the main branches, this is called *pollarding*. Poplars and willows are often pollarded, but other trees may be ruined by this process. Heading in may



Photograph by H. L. Hollister Land Co.

Fig. 166. Young plum tree, heavily loaded with fruit, grown under irrigation

be rendered unnecessary by removing the tips of the tender growth with the thumb and finger when it has reached the desired length. This latter operation is called *pinching* or

stopping. In annual plants pinching induces both branching and flowering. Melon and cucumber vines are often stopped to make them fruit earlier, and raspberries and blackberries are regularly pinched to cause branching. Since the majority of buds form twigs, the removal of the buds may take the place of pruning. This is called *disbudding.* In annual plants disbudding is often used to throw the strength of the plant into a few superior flowers or fruits. The florist regularly increases the size of chrysanthemum flowers by removing all but the terminal buds. Other forms of pinching that are self-explanatory are *topping*, *detasseling*, and *suckering.*

Root pruning. In rich soils trees sometimes fail to fruit because of too exuberant growth. In such cases fruiting may be induced by anything that will check the vegetative functions. This is often exemplified in trees that have been injured by lightning, defoliated by insects, subjected to an extended drought, or planted in sterile soil. Under any of these conditions they are likely to begin fruiting. A geranium plant blooms most freely when it has become pot-bound, that is, when the soil in the pot is crowded with roots, and removing part of the root system of a plant has the same effect. All fruiting may be regarded as a life-saving process, in that it provides the plant with a means for continuing the species, and any injury is likely, therefore, to call it into action. One of the most frequent methods in use is *root pruning*, in which a trench is dug around the tree and some of the feeding roots cut off, or a sharp spade may be driven into the soil at the proper distance for this purpose. The roots usually extend as far out as the branches; therefore the distance from the tree at which the roots should be severed depends upon its size. Care should be taken not to remove too many roots at one time, else the plant may be injured. The purpose is merely to check the growth. In some cases it is best to remove part of the roots one year and more the next.

Girdling. Removing a zone of bark from a tree will kill it because the plant food which passes down through the bark to the roots can no longer reach them and they die of starvation. Girdling a fruiting branch, however, may increase the size of the fruit it bears by retaining in it all the plant food made by the leaves. At the end of the season the branch, of course, dies, since the removal of the bark kills the cambium and prevents the formation of new ducts. In plants like the grape,

Photograph by H. L. Hollister Land Co.

FIG. 167. Young apple orchard in the Northwest

The darker specimens are peach trees which will yield several crops of fruit before they have to be removed to make room for the apple trees

where the fruiting branch is removed at the end of the season anyway, this method is occasionally employed. When a valuable tree is girdled, it may sometimes be saved by at once reducing the top to lessen evaporation, and protecting the wound until new bark can form over it. Bridge grafting may also be resorted to in helping the tree to cover the wound.

Cavities and broken limbs. When decay has been allowed to go unchecked until a cavity has been formed in the trunk

of a tree, the life of the specimen may be prolonged by filling the cavity with cement. Before putting in the cement all the dead wood should be removed and the cavity sterilized with any good disinfectant such as corrosive sublimate or copper sulphate. It is also well to give the cavity a good coat of paint or tar. If it is very large, concrete may be used as a filling and cement used to finish off the work. The edges of the cavity should be straightened up and painted, and under normal conditions, if the cement has been made just even with the wood, the bark should soon grow over the wound. When a limb has been partly split off from a tree, or when the trunk has been split by a storm, it may often be saved by bolting it together by an iron bolt extending through both parts. Binding the two together with wire serves only to increase the injury, since this soon stops the movement of sap and causes death to the parts.

Topiary work. That form of ornamental gardening in which trees and shrubs are sheared into grotesque forms, often simulating animals and the like, is called *topiary work.* For this purpose evergreen species are usually employed. Hedges, arbors, and arches are forms of topiary work. Other examples may often be seen in old cemeteries and on large private grounds. In the formal style of gardening the less grotesque forms are allowable, but all are out of place on home grounds.

PRACTICAL EXERCISES

1. Visit parks, private grounds, and the trees along the streets for examples of pruning. Do you find any trees that need pruning? any that have been badly pruned? Make suggestions for improvement.

2. If there are no trees in the school garden to be pruned, visit a bushy field or neglected roadside and practice upon the shrubs and trees found there.

3. Examine fruiting apple, peach, and plum trees, raspberry and currant bushes, and grapevines to discover where the fruit is borne. Later in the season identify the flower buds on species that form them in autumn.

4. If there are any trees in the neighborhood that have been pollarded, visit them for study.

5. Try the effect of girdling the branch of some tree that can be spared.

6. Pinch back melons, cucumbers, cosmos, and various erect-growing plants and compare the subsequent growth with that of others of the same kind that have not been so treated.

7. Visit cemeteries, parks, and large private grounds for examples of topiary work.

8. Remove all but the principal flower bud from a plant and compare the size of the single flower thus produced with that of the flowers on a similar plant that has not been disbudded.

9. If there are hedges on the school grounds, prune them; if not, select a desirable spot and plant one.

10. Select two tomato plants as nearly alike as possible. Remove all suckers from one as soon as they appear and allow the other to grow naturally. How does the fruit of the two plants compare in size? in number? in total weight?

11. Repair any cavities in the trees on the school grounds by the method described in this book.

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CHAPTER XVI

PLANT DISEASES

Origin. Plants, like animals, are afflicted with diseases which are caused for the most part by low forms of plant life belonging to the great group known as the Thallophytes. Most of these are bacteria or fungi — plants without chlorophyll and therefore reduced to the necessity of getting their food ready-made from other organisms. In nourishing themselves they tear down the tissues of the specimen upon which they have fastened, and in due time, if unchecked, may cause its death. Not all, however, thrive upon living things. There are vast numbers that find sustenance in the bodies of dead animals and plants and even in their cast-off parts. Of the latter type are the bacteria of the soil that turn dead vegetation into nitrates and the organisms of decay that resolve dead bodies back into the elements from which they came, thus relieving the soil of forms that would otherwise encumber it. We can easily imagine the confusion that would exist if all the leaves that have fallen in the forest had remained as they were when they fell. The majority of the fungi and bacteria must be classed as helpful species; it is only when they attack the things we value that they become enemies. As regards the manner in which they feed, plant pests may be divided into *parasites* and *saprophytes.* Parasites feed upon living things, and saprophytes upon dead ones. The organism preyed upon is called the *host.* In general, parasites are much smaller than saprophytes. The parasites are again divided into the *external parasites,* which live upon the exterior of the plant and send special organs into its tissues for food; and the *internal*

parasites, which, safe within the tissues of their hosts, bid defiance to most attempts to dislodge or kill them. All the fungi spread by means of *spores*, minute one-celled bodies that function like the seeds of flowering plants. They are often

FIG. 168. Live oak in Audubon Park, New Orleans, covered with Spanish moss (*Tillandsia*)

This is often regarded as a parasite, but it is an independent plant

given off in inconceivable numbers. The common field mushroom produces two thousand million spores. Others are capable of shedding a million spores a minute and keeping this up for several days. The largest puffballs may produce twenty million million spores. The spores are extremely small and

light and may float in the air for long distances before coming to rest, thus spreading the species very widely. Like other plants, they need warmth and moisture to grow, and increase most rapidly in warm, cloudy weather. The harmful bacteria in the soil may be carried from one field to another in the dirt

Fig. 169. Bacterial wilt of melons

From Duggar's "Fungous Diseases of Plants"

that adheres to the feet of animals, on the implements used in stirring the soil, and even by currents of water during rains.

Number of plant diseases. An immense number of organisms produce disease in plants, and if these could all live on the first species encountered, it is likely that few plants of any kind would come to maturity. Fortunately most plant diseases are restricted to a single species or a related group

of species; hence plants of one kind may be grown without danger close beside other kinds that are diseased. These organisms that cause disease are usually given the name of the effect they produce. Among the more familiar are the rots, smuts, rusts, mildews, blights, and wilts. Often the causal organisms are not closely related, but if they produce similar effects, they are likely to be named accordingly, just as a rise in temperature in man is called a fever, no matter what its cause. Some of the more common plant diseases are mentioned here; others may be found described in the reports of agricultural experiment stations and in manuals devoted to the subject.

FIG. 170. Mildew of cherry
From Duggar's "Fungous Diseases of Plants"

Rots. Many kinds of fruits and vegetables are attacked by rots which cause their tissues to break down into a watery mass and thus spoil the specimen. Good examples are found in the rot of apples and other fruits, carrots, cabbage, and the like. The wet rot of potatoes is another familiar form. Rots are caused both by bacteria and other fungi.

Wilts. The wilts are readily recognized from the fact that the leaves of the plant attacked begin at once to droop and soon after the death of the individual ensues. In many cases the wilting is caused by the fungus growing in the ducts of the plant and thus shutting off its supply of moisture.

Blights. Blights affect the leaves of plants, often causing them to shrivel as if touched by fire and soon resulting in their death. The potato blight may spread through an entire crop and effect its ruin in two or three days.

Fig. 171. Mildew of peaches
From Duggar's "Fungous Diseases of Plants"

Leaf spot. The leaves of plants are frequently attacked by fungi that cause discolored spots in the tissues. Sometimes these are sufficiently numerous to cause the death of the plant or render it unfit for food.

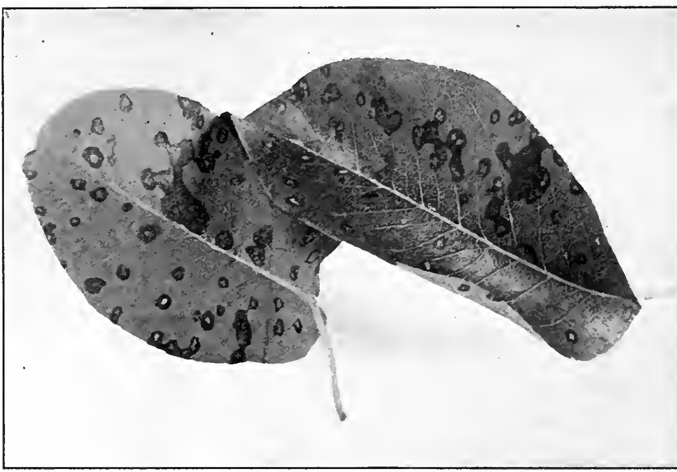

Fig. 172. Leaf spot on pear
From Duggar's "Fungous Diseases of Plants"

The brown spots that appear on bean pods and other fruits are closely allied to the leaf-spot diseases.

Molds and mildews. The molds and mildews may be either parasites or saprophytes. As parasites they cover the leaves of many species with a cottony or powdery growth which is

Fig. 173. Downy mildew on the grape.
From Duggar's "Fungous Diseases of Plants"

the plant body, or they push into the interior of the plant, whence later their spores are released. The plants are often called downy mildews, to distinguish them from other species. One form of mildew is nearly always present on the lilac, and

others are common on the grape, woodbine, and willow; in fact, there are few species of cultivated plants that do not

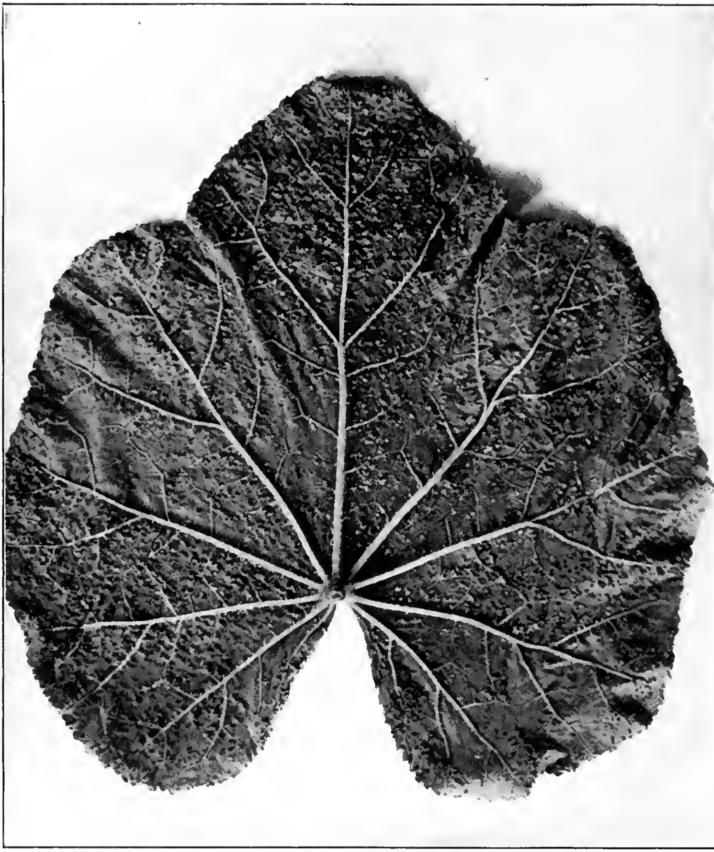

Fig. 174. The hollyhock rust

The small dots are the fruiting bodies containing multitudes of spores
From Duggar's "Fungous Diseases of Plants"

harbor some form of mildew. The damping-off fungus which attacks young seedlings at the point where the stem leaves the soil may be included in this group.

Smuts. The smuts cause the black powdery masses that are often to be seen upon corn, oats, and other grains. They are particularly fond of members of the grass family. Their spores germinate in spring soon after the seeds of the plants which they infect begin to grow. Getting into the plant through the stomata or through a break in the tissues, they grow with the growing plant until seeds begin to be formed. At this point they fill up the young seed with their own tissues and soon produce a mass of exceedingly minute black spores that float away to infect other plants, or that cling to the seeds of the plants upon which they grow, and are transported with them. The seeds of oats are often treated with formalin or hot water to destroy the spores before they are planted.

Fig. 175. Anthracnose of beans

From Duggar's "Fungous Diseases of Plants"

Rusts. The rusts cause rusty brownish or blackish patches on the leaves and stems of many plants. Fields of wheat or corn, late in the season, will furnish good examples, and others may be found in asparagus beds. Often the wheat rust is so abundant as to

ruin the crop. There are numerous species of rust, each restricted for the most part to a limited number of hosts. One of the most remarkable features of their life history is the fact that two different species of plants are usually required to complete their round of existence. The wheat rust is found in spring upon the barberry and not until later does it infect the wheat plant. The corn rust grows first upon a species of oxalis; the apple rust upon coniferous trees. Late in the season the rusts produce spores which last through the winter

Fig. 176. Apples affected by apple scab

From Duggar's "Fungous Diseases of Plants"

and set up the infection upon the first host plant again. It occasionally happens that the first of the two plants necessary for a complete life cycle of a rust is absent from the locality. In this event most species are able to omit this part of the cycle and begin at once upon the second host. Many rusts produce no less than four different kinds of spores.

Wound parasites. Many enemies of the woody plants are fungi that gain entrance through wounds, as where a branch has been torn off by the wind, or through a break in the bark caused by insects or mammals. These parasites live upon the old parts of the tree until well established, but ultimately extend to the living parts and cause their death. Often their

presence is not suspected until the spore-bearing parts appear, and then it is too late to eradicate them. The oyster mushroom and some of the shelf fungi are among the better known of the wound parasites. The entrance of such parasites may be prevented by promptly covering all wounds with paint or grafting wax.

Other plant diseases. The list of plant diseases is a very long one. It includes the black knot on plum, fire blight of

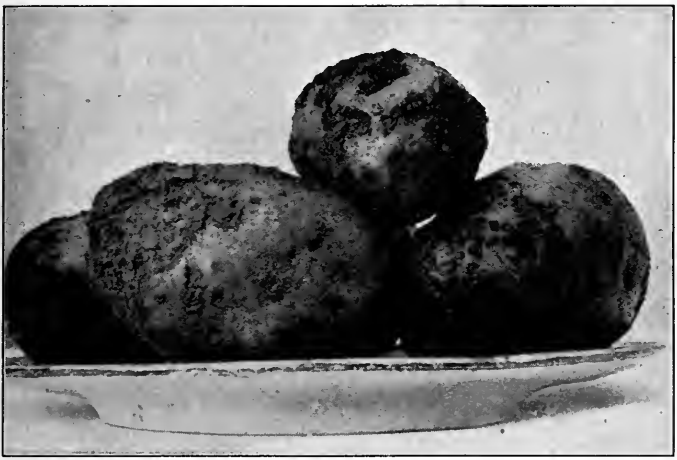

Fig. 177. Potatoes affected by potato scab

From Duggar's "Fungous Diseases of Plants"

the apple and pear, peach yellows, plum pockets, potato scab, cedar apples, witches'-brooms, peach-leaf curl, clubroot of cabbage, anthracnoses, and a host of others. It is usually not necessary to positively identify the organism causing the disease in order to remedy it, since what will control one disease will be likely to control all the others like it. The main thing is to discover the trouble before it has had time to spread, and to take prompt measures for its suppression. In a majority of cases the most efficient treatment is to spray with some

good fungicide, meanwhile removing all affected plants if the disease has progressed very far.

Sprays and spraying. The spray to be used for fungi depends partly upon the time of the year in which it is applied, and partly upon the kind of fungus to be exterminated. When the plants are leafless and dormant, the lime and sulphur wash is the one to be applied, while the Bordeaux mixture and the ammoniacal copper carbonate solution may be used as the buds begin to open and at intervals throughout the summer. As yet there is no known remedy against some plant diseases. Fire blight of the apple and pear, in which the branches die from the tip inward as if touched by fire, is one of these. The only way to save specimens attacked by it is to cut out the blight a foot or more below the part affected as soon as it appears. As a general thing, internal parasites are not injured by sprays, though they may be kept from spreading by such means. External parasites are usually killed outright. When in doubt as to the proper spray to use, it is a good rule to choose Bordeaux. Powdered sulphur sprinkled upon the leaves is also of use, especially in combating mildew.

Bordeaux mixture. The spray mixture adapted to the greatest variety of uses is undoubtedly Bordeaux mixture, made from lime and copper sulphate or "bluestone." A standard mixture consists of 5 pounds of copper sulphate, 5 pounds of lime, and 50 gallons of water. To make it, the lime and copper sulphate are dissolved in a little water in separate receptacles, and then further diluted with about half of the 50 gallons before mixing. If mixed without diluting, it makes a thick curdled mass that does not readily mix with the water. When properly mixed the liquid should be of a brilliant, sky-blue color. Three or four pounds of soap are sometimes added. The lime in this mixture is chiefly used to neutralize the copper sulphate, and it should always be in excess of the quantity needed for this. The solution may be tested by

dipping into it any bright piece of steel. If it has a coating of copper upon it when withdrawn, more lime should be added. Another test is to put a few drops of potassium ferrocyanide into a little of the solution. If it turns brick red, more lime is needed. If the potassium ferrocyanide remains yellow, sufficient lime is present. An excess of lime does no harm. The mixture here described is often known as the 5–5–50 solution, the numbers referring to the quantity of each ingredient employed. Other proportions may be taken: the 4–4–50 and the 3–3–50 are popular. The mixture should be strained before using. This spray does not poison insects, and if a poison is desired with it, arsenate of lead in the proportion of two or three pounds to fifty gallons may be added. Copper sulphate is often used alone with water in the proportion of one pound to twenty gallons. This can be used only before the buds open, never on the leaves.

Photograph by Bateman Manufacturing Co.

FIG. 178. Spraying a young fruit tree by means of a bucket pump sprayer

Lime-sulphur wash. For spraying all woody plants in the dormant condition, the lime-sulphur wash is preferred. It consists of fifteen pounds each of lime and sulphur and fifty gallons of water. To make it, bring the water to the boiling point and add the lime. Make a paste with the sulphur and a small quantity of hot water, add to the boiling

mixture, and continue boiling for about half an hour. Five or ten pounds of salt is often added while boiling. This mixture does not keep and should be used as soon as made. The wash may also be made by taking double the quantity of lime, slaking it with boiling water, and adding the sulphur while still hot; or the heat developed by the lime in slaking may be sufficient. This latter is called the unboiled wash.

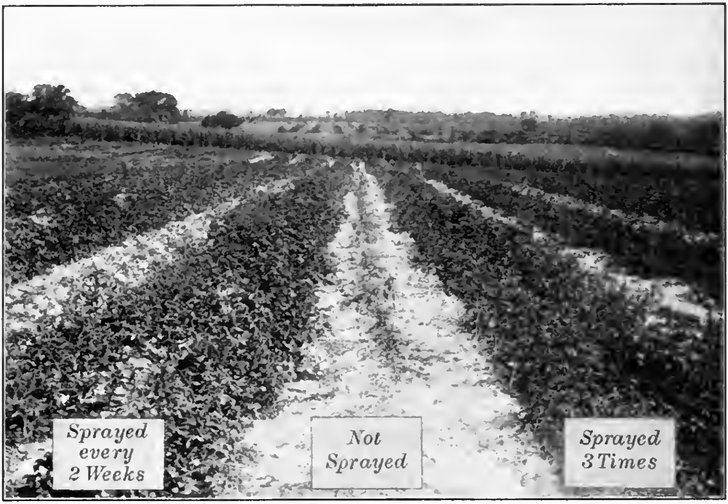

FIG. 179. Potato field attacked by late blight, showing the difference between sprayed and unsprayed rows

From Duggar's "Fungous Diseases of Plants"

Ammoniacal copper carbonate. This spray is made by adding five ounces of copper carbonate and three pints of ammonia to about fifty gallons of water. A paste is first made with the copper carbonate and a little water, the ammonia is added, and then the rest of the water. The mixture should stand until it settles, and only the clear liquid on top should be used. This spray is effective against rusts, leaf spots, and blights.

Potassium sulphide solution. The potassium sulphide solution is made by mixing one ounce of liver of sulphur with three gallons of water. It is used as soon as made, and is an excellent remedy for mildews.

Preventive measures. Since few plant diseases can be completely cured and many are only held in check with difficulty, it is wise to take every precaution against the entry of disease. Some plants are more resistant than others of the same species, and these should be grown. In some cases it seems possible to breed up a resistant strain. Disease always attacks the less thrifty individuals first. Plants should be kept in good health by proper cultivation and thus rendered more resistant. Diseased plants, when they occur, should be removed and burned. If allowed to remain, they only spread the trouble to other healthy individuals. Burning the plants kills the spores that might otherwise set up new areas of infection.

PRACTICAL EXERCISES

1. List the plant diseases known to be in your locality. Underscore the most destructive.

2. Tear apart decaying logs and examine the white threadlike growths which form the plant body of the higher fungi. See if you can trace the fruiting parts of puffballs, mushrooms, and shelf fungi to such plant bodies.

3. Examine the "smoke" from a puffball with microscope. The small objects seen are spores. Draw several.

4. Make a spore print by placing the cap or top of a mushroom, with gills down, upon a piece of clean paper. Cover with a bell jar or drinking glass for a day. The spores will be discharged in immense quantities. Some species have white spores, and these will show best if colored paper is used.

5. Make a collection of leaves and stems to show rusts, mildews, leaf spots, and smuts. These should be preserved, with proper labels, for the use of other classes.

6. Scrape off some spores from specimens affected with rust and examine with the microscope. The summer spores are one celled, but the winter spores are usually two or several celled.

7. Remove some of the ascocarps of lilac mildew from a lilac leaf (they appear to the unaided eye like small black specks) and examine with the microscope. Compare with the fruiting parts of any other mildew you can find. Crush the ascocarps to see ascospores and asci. Make a collection of mildewed leaves. The fruiting bodies, or ascocarps, are likely to be mature in late summer.

8. Make a collection of the fungi that grow on wood.

9. Visit museums for other kinds of fungi.

10. Make a collection of the different ingredients used in making insect sprays.

11. Make up standard solutions of the various sprays and use in the garden. If no plants there need spraying, spray those that are most likely to need it.

12. Visit a hardware or implement store and study the various forms of sprayers in stock.

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CHAPTER XVII

INSECT PESTS

How insects injure plants. After the young plants have broken through the soil with every indication of becoming thrifty and fruitful specimens, or after older and well-established plants have given indications of an abundant crop, a multitude of fungous and insect pests have still to be reckoned with by the gardener before a return for his labor is assured. Nearly all the insects that prey upon cultivated plants are so voracious and multiply in such numbers that the crop is sometimes destroyed in spite of every effort of the gardener to prevent it. It is estimated that insects and plant diseases cause more than a billion dollars' damage to crops each year. As regards the way in which they injure crops, insects may be divided into two groups — those with mouth parts adapted to chewing, and those with mouth parts adapted to sucking. The chewing insects harm the plants by eating stems and foliage, or by burrowing into fruits, stems, and other plant parts. The sucking insects do not defoliate the plant, but by sucking the juices from the tender tissues they are nearly or quite as harmful. Chewing insects may be controlled by poisons, but such substances have no effect upon sucking insects whose food comes entirely from the interior of the leaf. These latter must be fought with smothering sprays and gases.

Metamorphoses of insects. There are two general lines along which insects develop from the egg to maturity. In grasshoppers, crickets, katydids, and the like, the newly hatched insect has considerable resemblance to adult forms and gradually acquires the characters of maturity as it grows in size. Such

insects are said to have an *incomplete metamorphosis*. The great majority of insects, however, have a *complete metamorphosis*. When hatched they show no sign of the kind of adult insects they are designed to be. They begin life as wormlike creatures called caterpillars or worms, though it should be understood that they are not closely related to the true worms, such as the earthworm. The young worms, or more properly the *larvæ*, feed voraciously until they reach maturity, increasing rapidly in size and casting their skins from time to time as these become too small. When full-grown they stop feeding and either spin a cocoon about themselves or creep away into some safe shelter under a loose piece of bark, along old fences, or even in the soil, where they remain motionless for several days, weeks, or months, during which time they undergo great changes in form and structure. This stage is called the pupa stage and is the one in which large numbers pass the winter. At length there emerges from the dull and motionless pupa a winged insect, often brightly colored, which flies away to mate and deposit eggs upon the proper food plant and thus start the life cycle anew.

Forms of insects that cause injury. Crops may be injured by insects in either the larval or adult stage. An insect is seldom equally harmful in both stages. Usually the greatest damage is caused by the voracious larvæ, the mature insects often living on the nectar of flowers and frequently being beneficial as agents for the transfer of the pollen. In some cases the larvæ are much less destructive than the mature insects, possibly because they feed on plants that are not valued by man, while others, like the potato bug and the asparagus beetle, in both their larval and adult stages are injurious to crops. Some of the more harmful insects are mentioned in this book. Many others, less widely distributed, though often as destructive in restricted localities, may be found in any work on entomology. As with plant diseases,

it is usually not necessary to identify the exact species that causes the damage. It is sufficient to know how they injure the crops and to be able to adopt the methods that will most readily exterminate them.

Cutworms. Cutworms are dull, earth-colored, or striped worms that seek refuge in the soil during the day, coming out at night to feed. They cause immense losses to many cultivated crops, cutting off the young seedlings just as they appear aboveground and often following along a row until all the plants are taken. Some climbing species creep up the stems of plants and cut off their tops or even ascend trees to feed on the buds. In some grounds they occur in great numbers. Two hundred or more have been taken out of a single row sixty feet long. They are very hard to exterminate, owing to their nocturnal habits and manner of hiding, but they may sometimes be killed by putting poisoned food about their haunts. Clover, pigweed, or other tender vegetation sprayed with poison makes attractive bait. Cabbage, tomato, and other plants grown singly may be protected by a collar of stiff paper about the stems at the surface of the ground. When evidences of the work of cutworms is seen, the worms should be dug out and killed. This is easy, since they do not go very far to hide during the day. One method of keeping them in check is to pick them by hand at night by the light of a lantern. The half-grown cutworms spend the winter in the earth, and cultivating the soil up to the time of frost tends to reduce their numbers. The mature insect is a dull-colored moth of nocturnal habits and is seldom recognized.

Cabbage worm. The cabbage worm is a light green, smooth worm that infests cabbage, cauliflower, turnip, and other plants of the cress family. It feeds on the leaves, and when resting extends along the veins, which it so closely resembles as to be frequently overlooked. The worms may be easily poisoned. This does not injure the cabbage for food, since the leaves are

wrapped in such a way that the poison cannot penetrate to the edible portion of the head. The small white butterfly, so common in cabbage patches, is the mature form of this species.

Currant worm. Two broods of the currant worm occur annually : the first appears before the fruit is ripe ; the second about midsummer. The currant worm is a green- and black-spotted larva and so voracious that a small colony will defoliate a currant or gooseberry bush in a very short time if not checked. It is easily controlled by poisons, white hellebore being one of the best for use in small gardens.

Tomato worm. The tomato worm is a very large, smooth green worm with a hornlike projection at one end and oblique white markings on its sides. On account of its large size it is easily located by the gardener and falls an easy prey to parasitic insects. It passes the pupa stage in the earth and is often dug up when the ground is spaded in spring. At this stage it may be identified by a curved projection extending down one side like a handle. At maturity it becomes one of the sphinx or humming-bird moths often seen about long-tubed flowers in the late afternoon. A related species does much damage to crops of tobacco.

Corn-ear worm. The corn-ear worm is closely allied to the cutworms and army worms, but is found on or within the reproductive parts of the corn plant. It destroys the tassel by eating it off, and later creeps down into the ear between the husks and the cob, eating the kernels as it goes and ruining the ear for food. There is no known preventive for it at present.

Tent caterpillar. The webworms, or tent caterpillars, are readily recognized by the webs they spin on trees and bushes and within which they feed. These webs may be removed and the insects destroyed by burning them out with a torch made of a piece of cloth wound about the end of a pole and saturated with kerosene. A corncob soaked in oil and fastened to a pole also makes a good torch.

Codlin moth. The larva of the codlin moth is a small white worm that is often discovered feeding in the fruit of the apple. The mature insect lays her eggs in the blossoms and the very young fruit, and after the larva hatches out it enters the fruit, usually at the blossom end. To prevent its depredations the trees must be sprayed as soon as the petals fall and while the calyx is still open.

Curculio. The curculio is a small white worm that inhabits the fruit of the peach, plum, cherry, and similar species. The eggs are inserted just beneath the skin of the young fruit, and the worm hatches out and feeds upon the pulp. Poisons have no effect upon the worm, but the trees may be sprayed with poisons to protect them from the mature insect. Peaches, however, and stone fruits in general, are very sensitive to sprays, and instead of using such methods the trees may be jarred every morning for some days after flowering and the insects caught, as they fall from the trees, and burned.

Cankerworms. The cankerworms are also called inchworms, measuring worms, and spanworms. They eat the foliage of many plants, and, when disturbed, drop to the ground on the end of a long thread which they spin. The pupa stage is passed in the soil. The female is wingless and climbs the trees to lay her eggs. Her ascent may be stopped by a band of cloth or cotton around the trunk. Beneath this she will hide and may then be caught and killed.

Borers. Numerous species of borers infest the trunks of trees and occasionally other parts as well. They make their burrows in the wood and bark, weakening the stem, destroying the cambium, and causing the death of the tree. Their presence is indicated by small mounds of fine wood dust about the base of the trees, or by the gum that oozes out of the wounds in some species. Borers should be cut out as soon as discovered, or killed by pushing a stout wire into their burrows until it crushes them. In some cases a few drops of

carbon disulphide injected into their burrows with a small oil can, and the opening afterwards plugged up, is effective.

Elm-leaf beetle. The elm-leaf beetle is a small beetle that destroys the leaves on elm trees. It is very destructive, but at present is practically confined to the New England States. It may be controlled by sprays.

Cucumber beetle. The cucumber beetle is a small yellow- and black-striped insect that is very destructive to cucumbers, melons, and allied plants by eating the leaves of the seedlings. The young plants are sometimes protected by frames covered with screen, or they may be sprayed with poisons or dusted with white hellebore.

Blister beetles. The blister beetles are long-necked, black or gray insects that feed on the foliage and flowers of many species. They very frequently injure the flowers of composite plants, such as asters, by eating the ray flowers. Hand picking and spraying with poisons are the only remedies.

Potato beetle. The potato beetle is more commonly known as the potato bug. The mature insect is a nearly hemispherical creature with pale yellow and black stripes, and the larvæ are repulsive-looking red objects with black markings. This insect is usually most abundant on potato plants, the foliage of which is eaten by both the larvæ and the mature insects. Usually the plants are soon killed if they are not protected. Hand picking and spraying with Paris green or other poisons will keep the pest within bounds.

Fig. 180
A potato beetle

May beetles. The larvæ of the May beetle or June bug are the whitish grubs common in grasslands and not infrequently found in cultivated fields as well. They feed underground and often do much damage by eating the roots of plants. The mature insect is a brownish beetle familiar to all by its habit of buzzing around the lights in spring.

Plant lice, or aphids. Plant lice are small, usually wingless insects, black, green, orange, or white in color, that are found on the stems, the underside of the leaves, and even on the roots of plants. They increase in number with incredible rapidity, and when a colony gets crowded, winged individuals are produced that may spread the species to other plants. They suck the juice from the tender parts and weaken or kill the plants upon which they are allowed to thrive. One species that frequents lettuce, peas, and other cultivated crops is known as the green fly or green bug. Plant lice excrete a sweetish fluid that is greatly relished by ants, and the latter may usually be found in attendance upon them. Ants also contribute to the spread of the aphids by carrying some of them off to new pastures when the colony on a given leaf becomes crowded. The attendant ant of the corn-root louse actually carries the aphids off to a safe place and cares for them until the corn is up and then places them on the roots of the young plants, where they spend the rest of the summer.

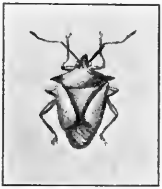

Fig. 181
A squash bug

Squash bug. The squash bugs are large angular insects found on the underside of the leaves of squash, pumpkin, and the like. They have an exceedingly disagreeable odor and are commonly known as "stinkbugs." The egg masses are conspicuous as large, shining brown patches and may be gathered by hand and burned. Kerosene emulsion may be used as a spray for the mature insects.

Mealy bug. House plants and the specimens of the florist often become infested with mealy bugs. These are small fuzzy insects, white in color, that suck the juices from plants and are hard to exterminate because ordinary sprays do not harm them. No absolutely certain remedy seems to be known.

Scale insects. In appearance scale insects are minute scale-like objects clinging close to the bark of young trees of many

kinds, often covering every available spot. The scale is a waxy substance secreted by the insect, and under this it lives, sucking the juice from the tree and multiplying rapidly. If not eradicated, it will ultimately cause the death of the plant. Strong sprays that can be used when the plant is dormant are most useful in combating this pest. The lime-sulphur spray used against fungous pests is also effective against this one, although it can be used in winter only.

FIG. 182. Scale insects on a maple leaf

Preventing attacks of insects. It is more difficult to protect plants from winged insects than from creeping ones, since the former can go from one plant to another through the air. Creeping insects may be trapped or repelled in numerous ways. The foliage of plants likely to be attacked may be sprinkled with ashes or slaked lime. Bands of sticky paper or tar may check the advances of climbing species, and whitewashing the trunks of trees will discourage many others. Small plants may be screened, but, in general, poisons and sprays are most effective. Bands of cotton fastened about the trunks of trees some distance from the ground are favorite hiding places for many insects, which may thus be easily caught and killed.

Poisons for chewing insects. For all kinds of chewing insects one of the poisons adapted to the purpose should be used. Of these the most useful for general purposes in the small garden is *white hellebore*, which may be procured at any drug store. This may be sprayed on the infested plants in the proportion of 1 ounce to 3 gallons of water, or it may simply be dusted on the foliage when wet with the dew. White hellebore is not so poisonous as some of the other remedies used, but its convenience serves to recommend it. *Paris green*, an

aceto-arsenite of copper, is a dry green powder extensively used upon field crops. It is made up in various strengths with water, 1 pound to 150 gallons being near the average. When used on stone fruits it is made much weaker, while for potatoes it is used stronger. In preparing it the poison is formed into a paste with 3 or 4 pounds of lime and a little water and is then diluted to the proper degree. The foliage

Photograph by Bateman Manufacturing Co.

FIG. 183. Spraying trees in winter to destroy scale insects

of many plants is injured by Paris green, and it is gradually being replaced by arsenate of lead, which does not have this defect. *Arsenate of lead* is a white pasty mixture that may be purchased of dealers in seeds or drugs. It is used as a spray in the proportion of 2 or 3 pounds to 50 gallons of water. The poison sticks well and does not injure the foliage, two qualities which make it desirable. Poisons should not be left where children and farm animals may find them.

Remedies against sucking insects. Poisonous sprays have no effect upon insects which suck the juices out of plants. These insects must be killed by suffocating them in various ways. One of the best and cheapest insecticides for this purpose is *Persian insect powder*, for sale by all druggists. It may be applied by means of a small bellows, and is very efficient in clearing insects out of small crevices where sprays have difficulty in penetrating. The standard spray is *kerosene emulsion*, made by adding 2 gallons of kerosene to 1 gallon of hot soft water in which half a pound of soap has been dissolved. This is then very thoroughly churned in order to make an emulsion that will mix with water. When wanted for use, it is diluted with from 10 to 30 gallons of soft water. The strong solutions are used for scale insects; the weaker ones for plant lice. *Whale-oil soap* is often used for house plants and greenhouse specimens. The spray is made by dissolving 2 pounds of whale-oil soap in 1 gallon of soft water. A strong soapsuds, made from any kind of soap (naphtha soap preferred), is also useful. *Tobacco water* is made by pouring hot water over a quantity of tobacco stems and allowing them to steep for several hours. This liquid is then diluted and used as a spray. In plant houses, cold frames, and the like, *tobacco smoke* is often relied upon for killing aphids. *Carbon disulphide*, which may be purchased of the druggist, is an ill-smelling liquid that turns to gas as soon as exposed to the air. It is heavier than air and may be used to exterminate ants and other vermin that burrow underground. A little of the liquid is poured into the entrance of the burrow, which is then stopped up. Carbon disulphide is very inflammable and should not be used where there are fires of any kind. In the larger operations of the horticulturist *hydrocyanic gas* is sometimes used. It is a deadly poison and must be handled with great caution. In fumigating with this, a tentlike covering is placed about the entire plant and filled with the gas.

Spray pumps. Many kinds of spray pumps designed to throw liquid upon the plants in minute droplets are for sale by dealers. Sprayers or atomizers quite effective enough for small gardens may be had for as little as fifty cents. Some pumps may be used with an ordinary bucket, and others are carried like a knapsack. For large fields spray pumps drawn by horses are used. In lieu of a spray pump the liquids may be sprinkled on the plants by hand, using a bunch of twigs or a whisk broom for the purpose.

Other aids in fighting insects. Although insects often multiply prodigiously and may suddenly become exceedingly numerous in a locality, it is seldom that an unusual increase

FIG. 184. A good form of hand sprayer

is long maintained. The number of insects averages about the same from year to year. This is doubtless due to the fact that each species has its own natural enemies, and when it becomes abundant, the species that prey upon it also become more numerous and soon reduce it. One of the most powerful of these enemies is the common *toad*. This animal lives entirely upon insects and is not very particular as to the kind. In the course of a single summer it destroys many thousands of harmful ones. Small *snakes* also live upon insects and mice, while the usefulness of *birds* as insect eaters is well known. A large number of the latter, among which are the woodpeckers, swallows, warblers, vireos, and wrens, are entirely insectivorous, while others that eat some seeds make insects

the bulk of their diet, seeming to prefer them to seeds. Even those listed as true seed eaters do not feed to any great extent upon the seeds of cultivated plants, and usually feed their young upon insects. Insects also have their contagious diseases, and may be exterminated by spreading the infection among them. Last, but by no means least, are the insects that prey upon others. The *dragon fly*, often called the mosquito hawk, feeds almost exclusively upon mosquitoes; the *tiger beetle* attacks and kills many kinds of insects; the *ant lion* preys upon ants; *ground beetles* eat the eggs of other species; the *spider* captures flies, grasshoppers, crickets, and the like; and certain wasps stock the larder for their young with captured flies. The *ladybird*, or *ladybug*, lives almost entirely upon aphids and scale insects, both in the larval and the mature state, and is one of the most effective aids we have in keeping these pests in check. Most remarkable of all, however, are the *ichneumon flies* which deposit their eggs in the larvæ of other insects. Some are equipped with long ovipositors, by means of which they are able to reach the larvæ of boring species, deep in the trunks of trees. When the eggs hatch, the young worms live upon

Fig. 185. Ladybug
Showing larvæ and mature insect

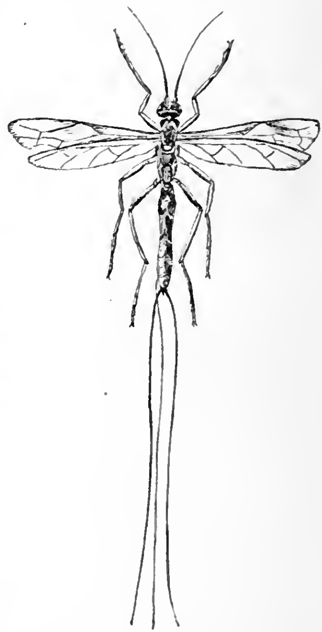

Fig. 186. One of the larger ichneumon flies. (About natural size)

the tissues of their host, instinctively avoiding the vital parts until, having reached maturity, they eat their way out to the air and spin their small cocoons upon the body of their host. Soon the perfect insect emerges and flies away to look for new victims, leaving the parasitized host to die. The tomato worm is very frequently parasitized, and a search in any large tomato patch late in summer will probably reveal many worms covered with the tiny white cocoons of the parasite.

PRACTICAL EXERCISES

1. Make a list of the insects injurious to plants in your locality, showing what crops they injure. Underscore the chewing insects in the list.

2. Place a cross before the names of insects in the preceding list that have been found in the school garden.

3. Make a list of the five most destructive insects in your locality and indicate whether it is the larvæ or perfect insect that does the damage.

4. Make a collecting trip for insects, securing, if possible, eggs, larvæ, pupæ, and perfect insects of the same species. This may be possible with the cabbage worm and a few others. Catch young crickets or grasshoppers and compare with mature forms.

5. Search tomato vines for parasitized tomato worms. Similarly, parasitized worms may be found on grapevines, the box elder, the apple, and many others.

6. Collect and label samples of all of the poisons used for combating insects.

7. Examine collections of insects for the dragon flies, ladybugs, ichneumon flies, ant lions, and other insects that prey upon harmful species.

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CHAPTER XVIII

PLANT BREEDING

Need for breeding. It is well known that fruits and flowers as they grow in the wild rarely attain the perfection of which they are capable under more favorable circumstances. The struggle for sufficient light and food materials, the constant conflict with insects and disease, and the vicissitudes to which the plants are exposed by the climate of the region all operate to reduce that vitality which otherwise might be expended in

Photograph by H. L. Hollister Land Co.

Fig. 187. Four potatoes to the yard

These are the result of irrigation farming

brighter flowers and larger, better-flavored, and more abundant fruits. All cultivation is in recognition of this fact; reduced to its simplest terms, it is the selection of the most likely plants, the supplying them with abundant food, and the protecting of them from their enemies. Cultivation always results in better and larger crops, but man has not been content to rest here. Having been taught by this experience that plants can be greatly modified by proper treatment, he is ever on the watch to extend his operations further and produce still better

specimens. This work of improving plants by inducing them to attain the highest development possible is called *plant breeding.*

Basis for breeding. The work of plant breeding is made possible by the fact that all plants tend to vary within certain limits. There is probably no species that is absolutely fixed as to type, though some vary more than others. Even in the plants which present the least amount of variation, nobody ever saw two plants or even two leaves that were exactly alike. Usually the plants that vary most come from families that contain great numbers of species; in fact, the species themselves may be looked upon as illustrations of greater variations from the original stock which have been developed through ages of natural selection. Every one is so familiar with the slight variations that occur in all plants that they seldom occasion remark. In any large area devoted to a single species we expect to find the tall and the short, the branched and the unbranched, the smooth and the hairy, the pale and the more deeply colored, the vigorous and the sickly, the drought-resistant and the less hardy. It is only when variation is manifested in the plant parts with which we are especially concerned, such as the size and color of the flowers or the abundance, size, and flavor of the fruits, that we notice it and endeavor to make these favorable variations permanent. That they can be made permanent, or even increased in value, is shown by the superior plants everywhere seen in cultivation. Strongly marked variations are usually apparent in the seedlings soon after they have started into growth, but others may not appear until the species has reached maturity. The point of departure for most plant

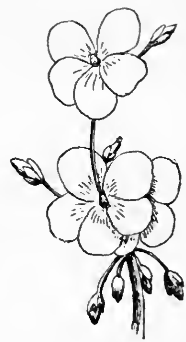


FIG. 188. A geranium sport, showing one truss of flowers growing out of another

breeding is found in the seeds, however. By repeated sowings of great numbers of seeds one will ultimately secure the material necessary for a start and can then breed from it. The common cut-leaved maple was not found until a million maple seeds had been sown, and it is said that a bushel of apple seeds were sown before that desirable form, the wealthy apple, was secured. The weeping mulberry was an accidental seedling that sprung into being fully developed, and the Lombardy poplar is regarded as a sport from the European black poplar. In the more permanent plants, such as shrubs and trees, variations occur which are often confined to a single branch or a single cluster of flowers. These are called *bud variations*. Good illustrations may be found in the nectarine, which is regarded as a bud variation of the peach, and in the seedless navel orange, which has been derived in the same way from the seeded orange. It is probable that variations from the normal are much more frequent in nature than we suspect, and the fact that they seldom persist is no proof that they do not occur. In the nature of things the plants of a region are better adapted to that region than any other set would be, and are thus able to hold the ground and crowd out any different forms that might arise. If, as may occasionally happen, the new form is better fitted to the locality than

Fig. 189. A nasturtium sport, showing the parts of the flower turned to leaves

Fig. 190. Columbine flower with parts turned to leaves

the normal plants, it may take possession of the field and exclude the others. When a variation in a plant makes it very different from the original, it is commonly known as a *sport*, or *mutation*. Thus a red-flowered form may suddenly appear among plants that normally bear white or yellow flowers, double flowers may spring up in the midst of single-flowered specimens, or well-flavored fruits may be discovered among inferior kinds. The Lucretia dewberry was derived from the wild dewberry in this way, and many of our bush fruits have had a similar origin. The Concord grape is another interesting example of a sport derived from a familiar wild plant.

Inducing variation. While one may occasionally find among wild plants a desirable specimen that has arisen from seed or bud variation, and transplant it to better quarters before the common plants of the region have overwhelmed it, the task of watching either wild or cultivated plants until such variations occur is a tedious one. Fortunately for the plant breeder, it has been found possible to hasten matters and to induce variation by manipulating the plants in various ways. Increasing the food supply is one of the most efficient means of producing variation. It seems as if many qualities latent in the plant are only brought out when food is abundant and all the other conditions for growth are favorable. A change in location may also cause plants to vary. When they have grown for any length of time in one region, they become in a measure specially adapted to it and have little further need of change; removal to a different region calls for new adjustments, and consequently favors variation. Farmers and gardeners often send to other localities for a change of seed, and it is believed that the practice of buying new seeds from the seedsmen each year, instead of saving seeds from the previous crop, may affect the character and variability of the new plants grown. A difference in the amount of light received by the plant is still another cause of variation. Pruning has a similar effect,

partly through admitting more light to the plant, and partly through checking growth processes. Injury to the plant may also result in variation. It is a remarkable fact that when the type has once been induced to "break," or vary, the tendency for the resulting forms to continue to do so is strong. A notable instance is found in the plant known as the Boston fern, which is frequently grown in the window garden. A few years ago a sport with much-divided leaves was put on the market, but it was soon eclipsed by numerous much finer forms that had been developed from it. When once a desirable variation has been secured, its value need not be jeopardized by further breeding. It may then be multiplied vegetatively; in fact, many improved plants will not come true from seeds, and their number must be increased in this way. Most of our fruits, flowers, and garden vegetables have arisen through variations from less desirable types.

Photograph by W. A. Terry

Fig. 191. Two leaf sports from the common Christmas fern (*Polystichum*)

Hybrids and hybridizing. Another way in which new plants may be obtained or variations started is by *crossing*, or *hybridizing*. In this process pollen from the flowers of one species, or variety, is applied to the stigmas in the flowers of another,

the resulting seeds thus having the characteristics of two different strains. The plants from such seeds are called *crosses*, or *hybrids*. A few hybrids between different genera are known, but usually only closely related species, or varieties, are likely to cross, and the closer the relationship the more successful the operation is likely to be. The apple will not hybridize with the pine, nor the strawberry with the milkweed. The reason species do not cross more readily is because the tendency in nature is away from such crossing. If it were otherwise, we would have an endless confusion of plant forms in which no type would be recognizable. Among the more interesting forms of commercial value that have been produced by hybridizing are the plumcot, a hybrid between the plum and apricot; the citrange, a hybrid between the trifoliate orange, or citron, and the sweet orange; and the tangelo, produced by crossing the tangerine orange and the grapefruit (pomelo). Among plants cultivated for their flowers, the canna, gladiolus, and orchid have been extensively hybridized.

Producing the cross. In crossing plants the essential thing is to protect from all foreign pollen the stigmas of the flowers to be pollinated. This is accomplished by slipping a small paper bag over the flowers just before they open, and tying the open end of the bag about the twig which bears them. If one is to be absolutely sure of his cross, the flowers that are to supply the pollen should be similarly treated. If the flowers contain both carpels and stamens, as is usually the case, there is a chance that the flowers to be crossed may be pollinated by their own stamens unless these are removed. It is customary, therefore, to cut away the corolla with a sharp pair of scissors before the flower expands, and remove the stamens with small forceps or the scissors. In plants like the pumpkin, cucumber, and corn, which bear their stamens and carpels in separate flowers, this treatment is not required, though the flowers should be protected from the wind, insects, and other

pollinating agencies. In pollinating the flower the ripe anther is crushed to expose the pollen, which is then thickly applied to the waiting stigmas. Fresh pollen is always best, but in a few cases, especially in orchids, it may remain alive for months. After pollination the flower is once more covered with the paper bag until the stigma is no longer receptive and the ovary has begun to increase in size. In all plants that bear both kinds of organs in the same flower two crosses can be made, the stamens of one plant supplying pollen for the other, and vice versa. Sometimes a considerable difference exists in the progeny of the two crosses, though usually there is practically none.

FIG. 192. Longitudinal section of flower and another prepared for pollination

Mendel's law. About half a century ago an Austrian monk named Gregory Mendel, while experimenting with different strains of peas in the monastery garden, discovered the curious law that governs the union of male and female elements by which hybrids are produced. An account of his experiments was published at the time, but the significance of the results did not impress the botanists of his day, and it was not until 1900, when the law was again independently discovered, that the importance of Mendel's work was recognized and the original experimenter given proper credit. Briefly the law is this: when two species, or forms, are crossed, the resulting hybrids tend to resemble one parent to the exclusion of the other. Thus if a red-flowered and a white-flowered form be crossed, the next generation is likely to have all red or all white flowers. If the flowers are red, we say the red color is *dominant* and the white *recessive;* or if the flowers are white, the red is

recessive and the white dominant. That the color said to be recessive is merely latent and not lost is shown when the next generation of plants is produced. Here the recessive color appears again in approximately one quarter of the specimens; and if these recessive plants are now bred together for generations, they will bring no plants of the other color. Quite a different state of affairs exists in the behavior of the remaining three quarters of the specimens. If the recessive color is white, then these latter will be red, but only about one third of them, that is, one quarter of the whole number of plants, will be capable of producing only red flowers in the next generation, and so on indefinitely. The remaining 50 per cent of the original number will produce as before, approximately one quarter pure red,

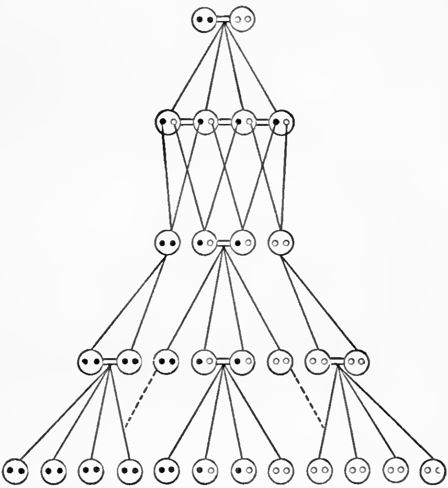


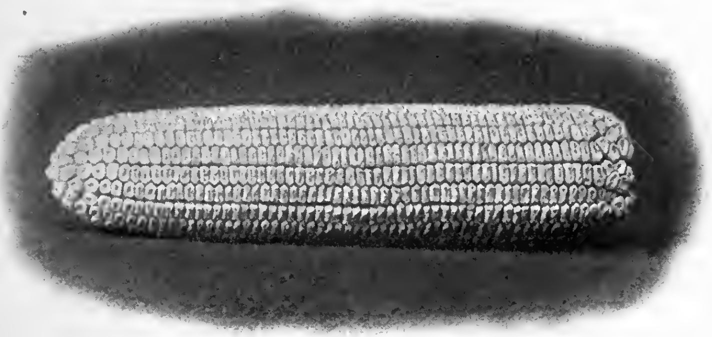
Fig. 193. Diagram to illustrate Mendel's law

one quarter pure white, and one half mixed, and this condition will continue through many successive generations. In explanation of this it is assumed that in the original white-flowered species all the gametes, or sexual cells, of the plant had the tendency to produce other white-flowered forms, and the equivalent cells in the red-flowered plants had a tendency to produce red flowers. When they are bred together, therefore, the resulting plants are bound to have a mixture of red and white gametes, one of which becomes dominant in this second generation. In the next generation, however, the male

and female gametes have another chance to pair, and this naturally results in some plants being produced from the pairing of two white gametes, and others from two red ones, while still others continue to be mixed as before. The example cited is probably much simpler than is usually the case in nature when a cross is made, since it is concerned with a single character only. It is likely that a similar relationship exists between each pair of contrasting characters in the plants hybridized, one character being dominant and one recessive in the first generation, but both appearing in the second in the proportions indicated. Smooth leaves may be recessive to downy ones, short stems may be dominant over long ones, large flowers dominant over small ones or the reverse. Thus the skillful cultivator is presented the opportunity of varying his plants in many ways by combining the characters differently. It must not be assumed, however, that all plants behave in the manner outlined in the foregoing. There are some crosses which are more or less perfect blends of the original forms, and others in which the characters do not appear to separate out according to Mendel's law in the succeeding generation. In others certain characters may blend, though the species as a whole behaves according to the law. What these characters are and how they function in crossing is still a subject for investigation. Crossing two forms in which some of the characters are alike may also result in intensifying these characters.

Selection. Variations of whatever kind merely offer opportunities for plant breeding; they give different plants, not necessarily better ones. The new forms are possibly as frequently below a desired standard as above it. Any permanent improvement must be made by careful and wise selection. The gardener practices a certain form of plant breeding, though possibly unconsciously, when he selects seeds from his best plants for producing the next year's crops. To achieve

any noteworthy success, however, the plant breeder must have an ideal type clearly in mind and breed toward it. No progress will be made if the ideals are constantly changing and the plants selected for one feature one year, and another feature the next. By keeping the desired form constantly in view, taking advantage of all favorable variation and always selecting the best, a steady advance may be made for a series of years. Now and then a sport may develop which will suddenly carry the work forward with a bound, but usually the small variations must be depended upon. There is a point, however,



Photograph from Bergen and Caldwell's "Practical Botany"

FIG. 194. A prize ear of corn that sold for two hundred fifty dollars

beyond which each plant refuses to go. It would probably be impossible to produce tomatoes as large as pumpkins, though the size might be greatly increased by selection and, in fact, has been. Nor is it likely that a blue-flowered form could be developed from one with red flowers, though the color in the blue flowers might be varied greatly by such means. The average amount of sugar in sugar beets has been raised from 8 per cent to 18 per cent within a very short time, while single specimens have been found with much higher sugar content. In plant breeding it is usual to pay more attention to the average advance than to single cases, since

widely aberrant forms are seldom stable. It is better to breed from a plant, all of whose members show some advance along the lines desired, than to breed from one which shows a greater advance in a single member. In breeding for large flowers, for instance, one should select plants in which all the flowers are a little larger, rather than a small-flowered form which may produce one or two superior blossoms. It is also desirable to breed for one thing at a time, or, if more is attempted, to choose characters which will not conflict in developing.

Roguing. After a form has been developed to a point where its superiority to the common form is apparent, it cannot be depended upon to continue in this state without assistance. Left to itself it will soon "run out," that is, it will return to the general average of the type, and the improvement gained by breeding be lost. When the plants have acquired the desired form, further variation is undesirable and effort must now be directed to fixing the type. All plants, therefore, that are not close to the ideal form should be destroyed as soon as detected, to prevent the good and bad plants from mixing by pollination. This is called *roguing*. If one is endeavoring to breed a certain strain of plants, he will sow as many seeds as possible, preserve only the best for subsequent breeding, and destroy the others.

Xenia. When a cross between two plants is made, any differences due to the union will not appear until a new generation has been grown from the seeds resulting from the cross. In certain cases, however, the seeds themselves, or even the fruit, may show the effects of crossing. A good illustration may be had in corn, which readily mixes when two sorts are grown together. This effect is known as *xenia*. Ordinarily, when a plant is fertilized, a single gamete from the pollen tube unites with another in the ovule to form the cell from which the embryo is produced. In cases of xenia another gamete

from the pollen tube unites with the nucleus of the cell in which the female, or egg, cell is located, and this, though unable to form an embryo, may nevertheless grow and form part or all of the endosperm, or albumen, which usually surrounds the embryo in the seeds. In the corn, xenia affects only the endosperm, though the fact that the second union of cells has been made is proof that the embryo in such seeds has also been produced from the sexual cells of two different strains.

Parthenogenesis. While it is the rule that neither seeds nor young plants result from flowers unless fertilization takes place, there are not a few species that are able to produce new embryos without this process. The production of young plants in this way, from what are essentially unfertilized eggs, is called *parthenogenesis.* This phenomenon is not entirely confined to plant life. The aphids, or plant lice, reproduce by parthenogenesis, and there are sometimes as many as thirteen generations of parthenogenetically produced females before a generation containing males is produced. Parthenogenesis differs from ordinary vegetative reproduction in plants in that it always results from an egg cell, while in vegetative reproduction any part of the plant may give rise to a new plant.

PRACTICAL EXERCISES

1. Find the amount of variation that is exhibited by a hundred specimens of one kind selected at random, counting or measuring the parts as necessary. The following list is suggestive: pods of catalpa (variation in length and diameter); peas or beans (number in pod); sepals (colored organs) in hepatica (variations in number; in color); petals of bloodroot (number); ray flowers of daisy, sunflower, or other composite (number); lobes of the leaves in mulberry (number); leaves in poplar or apple (width and breadth); leaflets in mountain ash, locust, or rose (number); fruits in a cluster of currants or grapes (number). In counting or measuring make a column of figures in numerical order, and opposite each figure make a straight mark each time a count falls upon it. Every fifth mark is made across the preceding four, so that the

marks may be counted by fives. In the illustration which represents the variation in the ray flowers of 55 specimens of sunflower the lowest number of rays found was 12, and five specimens possessed this number. The highest number was 20 with only one plant showing it. The average was 15, twelve heads possessing this number. The same data can be expressed by a graph, similar to the one on page 52, in which the squares may represent the number of parts in one direction and the number of specimens in the other. Express your work by both methods.

Fig. 195. Variation in the ray flowers of sunflower

2. Visit any considerable area of one crop, wild or cultivated, and select the specimens you would breed from if you desired to get (*a*) larger flowers, (*b*) more vigorous plants, (*c*) deeper color, (*d*) more abundant fruit, or (*e*) broader leaves.

3. Visit any patch of flowers in full bloom and search for variations in color, size, and number of parts in the flower.

4. In a row of young seedlings select those that are (*a*) most vigorous, (*b*) weakest, (*c*) deepest in color, (*d*) palest, (*e*) with broadest leaves, and (*f*) with narrowest leaves. Are the differences great enough to be readily noticeable? Would they affect the crop?

5. Visit and examine any sport that may be growing in the neighborhood, especially the cut-leaved maple, Camperdown elm, weeping mulberry, single-leaved mountain ash, single-leaved locust, nectarine, purple-leaved plum, purple-leaved barberry, golden elder, yellow raspberry, and the like. Compare with normal plants.

6. In the school garden or other convenient place cross-pollinate one or more flowers. Make a reciprocal cross in others. If two desirable varieties are crossed, save the seeds for the next class to use.

7. Plant hemp seed and study the difference between the male (staminate) and the female (pistillate) plants. Examine cucumber or melon plants and distinguish pistillate and staminate blossoms.

8. If seeds of hybrid plants are to be obtained (perhaps left by a previous class), grow the plants to observe the workings of Mendel's law.

9. Pick out two antagonistic strains in some garden plant, such as tall and short, broad-leaved and narrow-leaved, large flowers and small, and by selection breed up two different races. Leave the seeds for the next class to use in continuing the experiment. Be sure to make a full record of your work for future reference.

10. Examine ears of corn that have mixed for illustrations of xenia. Cross-pollinate corn of two different colors and observe the effects.

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CHAPTER XIX

THE ORIGIN OF SPECIES

Evolution. Everything in nature is subject to change. No sooner is a form produced or a structure completed than it begins to be modified by many agencies. Ultimately it grows old, slowly deteriorates, and finally disappears. Such changes have always been in existence. We know from the fossil animals and plants found in the rocks that there has been a steady succession of different forms in the world, beginning with the strange and incongruous forms of past ages and ending with the species of the present day. The fact that such forms are embedded in the solid rock shows that the very rocks themselves have changed since animals and plants first inhabited the earth, and also indicates how very profoundly our planet has been modified since time began. When we realize that the one unchanging feature of existence is change, it is easy to appreciate the fact that the plants and animals of our day are quite unlike those that first inhabited the earth. All have changed with changing conditions; indeed, within the memory of living men some of our flowers and fruits have been greatly modified in this way. Our present species, then, appear to be the latest forms in a long line of descent — the last links in a chain that might be traced back to the dawn of creation. The process by which our modern plants have come to be what they are, the steps by which they have changed, little by little, are included in the term "evolution." It is usual to assume that evolution has always progressed from the simple to the complex, and so it has in most cases; but evolution may proceed in any direction useful to the organism, and the best we can say of it is that it works through change.

Struggle for existence. Every plant is able to ripen many more seeds than are needed to reproduce the original specimen. In some annuals nearly a million seeds may be produced, and the perennials often do as well and continue to do so for many years in succession. But the earth is already so densely populated that there is no chance for all the plants from these seeds to come to maturity, even if they escape the multitude of dangers that attend them on every side. Many of the seeds fall in places where germination is impossible, — on rocks, in roads and streets, in streams and ponds, — and others are eaten by birds, insects, and other animals. Those that germinate are subject to plant diseases and the attacks of insects, late frosts may cut them down, the hot sun may burn them up, and drought may cause their death. Many spring up in the shade of other plants or in uncongenial soil and die for want of food, while the crowd of other plants seeking the same advantages with regard to light and food materials is so great that only the exceptional individual is able to survive. Thus there is a very real and constant struggle going on, a struggle of species with species, of individual with individual, and all with the untoward forces of nature. As applied to plants and animals this is called the *struggle for existence*, and it results in the *survival of the fittest.* Here we discover one reason for the numerous seeds produced by plants. The greater the number produced, the greater the chance that at least a few will survive to replace the original form.

Natural selection. The plants that survive all the vicissitudes of nature and finally come to maturity are, as we have seen, those that in the long run are best fitted to survive. A slightly larger amount of food in the seed may have given them a start over weaker plants in the vicinity, a more rapidly growing root may have brought them into contact with moisture sooner, the ability to get along with less light may have enabled them to survive, or any one of a hundred other things

may have given them some advantage over their competitors and helped them to hold their lead in the race. Those less able to carry on the struggle ultimately and inevitably perish. Thus there is in nature a constant and widespread selection of the best, quite akin to that which man exercises, with this difference, that in natural selection the plants are steadily adapted to their habitats and the species and varieties kept up to standard; while in artificial selection, such as man practices, the aim has been to produce better strains for certain purposes without regard to the ability of the plant to survive in the struggle with other plants, since cultivation relieves the plant of much of this struggle. This explains why our garden plants are so easily overcome by weeds. They have been cultivated so long that they have lost the power to take care of themselves. The weeds, on the other hand, have been developed into most efficient plants both by nature and by the hand of the gardener. Only the most resistant could withstand the two.

Results of variation. Without variation evolution would be at a standstill and no possibility of improvement would exist. The tendency of plants to constantly vary in different directions has saved whole races from extinction, while the inability to change with changing conditions has as certainly caused the death of many others. Plants are never perfectly adapted to their habitats, but variation enables them to fit into the plant covering of the region with the least friction, while nature constantly weeds out the unfit. Usually the changes in plants are cumulative, and, given sufficient time, two plants nearly alike at the beginning may ultimately come to be very different if exposed to different conditions. It is not difficult to see that all the plants which now inhabit the earth may have been derived from a single primitive form through long ages of variation. This explains the existence of many plants of the same general type — they have been

derived from a common ancestor in the not far distant past. In the case of plants that less closely resemble one another, it is conceivable that the common ancestor has existed farther back in the line of descent.

Darwinian theory. Ever since man began to think about plants he has speculated more or less as to their origin. Although the great mass of people have always believed that plants have existed unchanged from the beginning, there have been people in every age to point out evidences of change, and it was early suggested that plants have descended from earlier and different forms through modifications of structure. For many centuries proofs of this idea accumulated, but the whole subject did not receive adequate treatment until Charles Darwin issued his "Origin of Species" in 1859. In this book was gathered a great mass of facts in support of the contention that all plants and animals have arisen by the slow processes of variation and natural selection, and to this theory of organic descent the name of the *Darwinian theory* has come to be applied.

Mutation theory. As the study of nature has progressed, many instances of evolution have been encountered that are difficult to reconcile with the Darwinian theory. While the main features of evolution have not been questioned, there has seemed to be need of additional explanations to account for the origin of certain forms which it is difficult to imagine could be produced by gradual changes. These are supplied by the *mutation theory* of Hugo De Vries. This new theory does not take the place of the Darwinian theory but rather supplements it. The new theory holds that new species do not always arise from old ones by a succession of slight modifications, but that they may spring into being fully developed, much as sports and bud variations appear among cultivated plants. This theory is capable of experimental proof, and De Vries has produced a number of distinct forms from a single

sowing of seeds of certain species. Following this, it has been shown that many of what the botanist calls species are made up of numerous simpler forms grouped around a certain type. These forms are known as *elementary species* and agree pretty closely with what the gardener calls forms or varieties. Elementary species may be separated out of the botanical species by breeding. More than two hundred such forms have been produced in Europe from the species called *Draba verna.* It is supposed that many plants are constantly throwing off such forms, but owing to the crowd of plants better adapted to the locality, these seldom have a chance to mature. New forms are able to persist only when they are better adapted to their habitat than their parents are. It therefore appears that species have arisen by either of two methods — by slow modifications or by sudden sports, or mutations. Having arisen, however, they at once fall under the influences that result in further change, and so long as their development is in harmony with their position in life, so long will they exist to carry on the family line.

PRACTICAL EXERCISES

1. In spring visit a weed patch, a neglected garden, or other waste ground, and note the number of seedlings springing up. See if you can discover any that are leading in the race for light and air. What do you think gave them this lead?

2. Measure off a square yard on the lawn or in a pasture and count and name the different kinds of plants found growing in it.

3. Take any abundant plant and count the seeds produced by a single specimen. If each seed produced a mature plant capable of ripening a similar number of seeds, how many years would it take to produce one plant for each square foot of soil in the world? Why does not your particular plant become as abundant as this? Give two reasons.

References

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CHAPTER XX

OUR CULTIVATED PLANTS

Origin. It is a matter of common knowledge that all the plants at present cultivated in the world have been derived from wild ancestors. In some cases the very species from which they originated are still in existence, but more frequently the plants have been so long in cultivation, or have been so greatly changed by this process, that the species from which they have been derived are not to be recognized, and even the place of origin of some is unknown. The manner in which the selection of these plants first began is easily imagined. Owing to the tendency of plants to vary, there must always have appeared, here and there in the wild, plants that bore superior fruits and seeds. These even the wild man would prefer and in time would come to protect both from the encroachments of less desirable plants and from other wild men who might wish to appropriate them. When it occurred to some genius of that far-off time that the valued plant could be better protected by removing it to the vicinity of his hut, agriculture may be said to have begun. As more and more plants came to be protected in this way, the best were naturally selected, and so through hundreds or thousands of years our grains have been bred from wild grasses, our potherbs from thick-leaved species with edible qualities, our fruits from the smaller, less juicy, and poorly flavored forms of wood and glen, and our seed crops from those plants which, either by reason of their size, abundance, or the ease with which they are gathered, offered a promising field for the grower. The work has undoubtedly been helped along by sports that have

occurred from time to time, both in cultivation and in the wild, and which have brought to the gardener much better varieties than he could produce by years of selection.

Edible parts of plants. Instances are comparatively few in which the entire plant is used for food. Young beets and turnips are often used in this manner as potherbs, but usually only a part of each plant is considered edible. Ripe fruits are the only parts that seem to have been made to be eaten. The juicy pulp that surrounds the seeds of some species is supposed to have been developed for the purpose of attracting animals and thus securing the distribution of the seeds; but when we eat the seeds themselves, as in the case of peas and beans, or the roots, stems, and leaves of other species, we take what the plant has laid by for itself. There is scarcely a plant part, however, that man does not find edible in some species. In practically every instance, no matter what part is used, it will be found to be that in which the plant stores its reserve food. In the carrot, parsnip, salsify, and radish it is the root that is eaten; indeed, the word "radish" is derived from a Latin word meaning "root." Stems in general are too tough to be palatable, but we must not overlook in this connection the young stems of asparagus, the swollen stems of kohl-rabi, or the underground stems of the potato and Jerusalem artichoke. Lettuce, endive, chard, spinach, and cabbage are good examples of plants that are eaten for their leaves, while several others are valued for their leafstalks or petioles alone, among which may be mentioned rhubarb, celery, and sea kale. The young flower buds form the edible parts of the cauliflower and globe artichoke. Peas and beans are true seeds, but the grain of corn is a fruit, and so are melons, tomatoes, and peppers. The greengrocer usually divides his wares into the two groups, fruits and vegetables, and while there can be no question about the vegetables, since even the fruits are vegetable in origin, many of the things he calls vegetables are certainly fruits also.

Root crops. Most of our plants with edible roots are little changed from the originals. This is quite natural, since the only improvement desired has been the increased size of the roots and a greater storage of food. The *beet* is a native of the Mediterranean region and still grows wild there and as far east as Persia. The *carrot*, *turnip*, *parsnip*, and *radish* are found in southern and central Europe, and, all but the turnip, having escaped from cultivation in this country, have shown themselves able to maintain an existence in the wild state. *Salsify*, or *vegetable oyster*, like the beet, still grows wild in the Mediterranean region. From the garden beet the *field* or *sugar beet* has arisen, and from the turnip comes the *rutabaga*. The potato, though in no sense a root, is usually classed with the root crops. It is a native of western South America, where its relatives still abound. It was cultivated by the natives of the region before the discovery of America, but does not seem to have been known to the North American Indians. The *sweet potato* is a true root, the product of a plant belonging to the morning-glory family. It is regarded as a native of South America, but has long been in cultivation in China and is thought by some to have had a separate origin in each country. The *Jerusalem artichoke* is a species of sunflower, which grows wild in the Northern states and Canada, and was occasionally cultivated by the Indians before the advent of the whites.

Leaf crops. Chief of the plants grown for their leaves is the *cabbage*, which is still found in the wild state in the south of England, the Channel Islands, and on the shores of the North Sea. The wild plant has thickish leaves, but it is quite unlike the hard-headed specimens of our gardens. From this same plant has come a long list of varieties that are valued in cultivation, such as *kale*, *cauliflower*, *Brussels sprouts*, *kohl-rabi*, and the like. *Lettuce* came originally from the Mediterranean region, but is now widely distributed in both the Old World and the New as a pernicious weed. It is not easy to realize

that the weedy, prickly lettuce of waste places and neglected gardens is the same species as the tender, smooth-leaved, solid-headed plant so highly valued in cultivation. The lettuce was once grown for its loose leaves, which were little changed from the original, but nowadays it has been bred to make solid heads like a cabbage. The *spinach*, which much resembles the lettuce in form, has been known since earliest times. It is a native of Persia. The *onion* is another species valued for its edible leaves, though many think the bulbous part is a root. It is, however, a true bulb made up of the thickened bases of the leaves. The cultivated onion is a native of western Asia and has been known for centuries. Many other species grow wild in both Europe and America. The *leek* is a species of onion and grows wild on both sides of the Atlantic. *Celery* has long been in cultivation, but may still be found wild in parts of Europe and western Asia. It belongs to the same plant family as the *parsley*, *parsnip*, *carrot*, *fennel*, *dill*, *coriander*, and other species valued for their aromatic seeds. *Asparagus*, though not a leaf crop, may be mentioned in this connection. It has been cultivated for many centuries, and is, of course, a native of the Old World. In the wild state the stems of asparagus are rather slender, but under proper cultivation they reach a diameter of more than an inch.

The legumes. Some species of legumes seem to have been among the first plants cultivated by man. The seeds of peas and lentils have been found among materials referred to the Bronze Age of Europe. The word "legume" comes from the Latin *legere*, meaning "to gather," and seems originally to have been applied to any species of plant gathered by hand. The seeds of the plants now called legumes were usually prominent in such gathered crops, and the name has since come to be restricted to them. The *lentil*, little grown in America, has long been cultivated in the warmer parts of the Old World, especially in the Mediterranean region, and the *pea* has

probably been derived from a wild species growing in the same region. *Beans*, at least the common varieties, have come from South America. The *soy bean* and *cowpea* are natives of China.

Solanaceous fruits. Several edible fruits are produced by the nightshade family (Solanaceæ). This family contains many poisonous species, though the fruits are usually edible. In addition to the food plants, the family contains the tobacco plant and the petunia. Of the species grown for their fruits the *tomato* takes first place, although the latest of the group to be used as food. Less than a hundred years ago it was regarded as poisonous and was grown only for ornament under the name of love apple. The tomato is still found wild in its native land, Peru, but is now grown almost the world over. The fruit has been greatly increased in size by cultivation. The *red pepper*, *husk tomato*, and *eggplant* are relatives of the tomato. The first two are of American origin; the last is said to be a native of southwestern Asia. The *wonderberry*, or *garden huckleberry*, is a species of nightshade developed from a common weed in the central and western states. It may be mentioned in this connection that the potato is the enlarged underground stem of another species of nightshade.

Gourd fruits. Some species of the gourd family are poisonous or unfit for food, but the group also contains a large number of edible species. They all have long and weak stems that spread out over the ground or climb on other plants, trellises, and the like. The *cucumber* is one of the oldest of this group in cultivation, having been known in China for quite three thousand years. The *melons* are natives of Africa. The *watermelon* still grows wild in central Africa, and the *muskmelon* extends eastward and northward to western Asia. The *pumpkin* is a native of America, and was cultivated by the Indian in his cornfields at the time of the discovery of the continent, just as it is still cultivated.

The grasses. With the exception of *maize*, or *Indian corn*, all the grasses cultivated for food are natives of the Old World. The list includes *wheat*, *oats*, *barley*, *rye*, *millet*, *sugar cane*, *sorghum*, and *rice*. The grains have been cultivated so long that the origin of most of them is lost in antiquity. *Wheat* has been cultivated at least five thousand years. *Rice*, though cultivated in ancient times, still exists in the wild state, but it is a question whether wild wheat can now be found. *Indian corn* is a product of the warmer parts of the New World and was cultivated by the Indians long before the time of Columbus. It is not native to the Old World. Englishmen use the word "corn" for several kinds of grain, and when references to corn are encountered in early English literature and in the Bible, it should be understood that the grain we call corn is not the one meant.

Bush fruits. All the common bush fruits, *raspberries*, *blackberries*, *currants*, *gooseberries*, and the like, grow wild in both Europe and America. Some of the species in cultivation are of Old World origin, others have originated on this side of the world, and some are hybrids between them. They are usually but little changed from their wild relatives, the most noticeable difference being found, as would be expected, in the larger fruits.

Tree fruits. Our tree fruits are all closely related and belong to groups allied to the rose family. They have been cultivated from the earliest times and are much modified in consequence. The *apple*, *cherry*, and *peach* are natives of western or southern Asia, the *pear* comes from Europe, and the different species of *plums* are found both in Europe and America. The *grape*, while not a tree fruit, may be mentioned here. Nearly all the common varieties cultivated in eastern and southern North America have originated from native species. The European grapes do not thrive in the eastern states, but are extensively grown on the Pacific coast.

New fruits. That there are many other plants in the wild which might be made to take the place of plants now cultivated is beyond question. Those that have been developed are without doubt those that first came to hand in a promising form, but many still remain that, with the same amount of care in developing, would yield equally valuable results. We neglect the common elderberry, the wild crab, the many species of hawthorn, the papaw, the persimmon, wild rice, and many others simply because we have other species as good. The huckleberries and blueberries are just being brought under cultivation, and the cranberry is essentially wild, though cared for and even planted in bogs suited to its requirements. Even in the wild state these are very desirable plants. Calling to mind, however, the advances made by other fruits when carefully cultivated and selected, it seems likely that these and many others may yet be made to yield much finer fruits than they now produce.

PRACTICAL EXERCISES

1. Make a list of the wild fruits, seeds, roots, and leaves that you know are edible.

2. Make a list of the wild plants with which you are familiar that are related to cultivated crops.

3. Make a list of wild species that you think would be valuable for domestication.

4. What do you conclude to be the greatest obstacle to introducing them into cultivation?

References

Bailey, "Evolution of our Native Fruits."
Bailey, "Survival of the Unlike."
Davenport, "Domesticated Animals and Plants."
De Candolle, "Origin of Cultivated Plants."
De Vries, "Species and Varieties; their Origin by Mutation."
Sargent, "Corn Plants."
Willis, "A Practical Flora."

APPENDIX

SEVENTY-FIVE SHRUBS USEFUL FOR PLANTING

[With notes on their height, color, time of blooming, etc.]

Alder, white (*Clethra alnifolia*) : 4–10 feet ; white ; summer ; flowers very fragrant.

Almond, flowering (*Prunus Japonica*) : 3–5 feet ; pinkish ; spring.

Ash, prickly (*Zanthoxylum Americanum*) : 6–8 feet ; yellowish ; spring.

Azalea (*Azalea nudiflora*) : 6–15 feet ; pink ; spring.

Barberry (*Berberis vulgaris*) : 4–7 feet ; yellow ; spring ; stems thorny ; fruit scarlet, persisting into the winter ; used for jelly.

Barberry, Japanese (*Berberis Thunbergii*) : 2–4 feet ; yellowish ; spring ; thorny stems ; fruit scarlet, in small clusters, persistent ; much used for low hedges.

Barberry, purple (*Berberis vulgaris* var. *purpurea*) : 4–6 feet ; yellowish ; spring ; leaves purple-tinged ; used for hedges.

Bladder nut (*Staphylea trifolia*) : 6–12 feet ; white ; spring ; pods large, three-angled, inflated ; flowers in racemes.

Box (*Buxus sempervirens*) : 4–6 feet ; greenish ; spring ; leaves small, evergreen ; much used for hedges.

Buckthorn (*Rhamnus cathartica*) : 8–12 feet ; whitish ; spring ; thorny and much used for hedges ; fruit black.

Buffalo berry (*Shepherdia argentea*) : 6–8 feet ; yellowish ; late spring ; fruit red, edible ; leaves silvery-scaly beneath.

Burning bush (*Euonymus atropurpureus*) : 8–12 feet ; purplish-red ; early summer ; fruit pale pink, at length splitting and showing the scarlet aril which surrounds the seed.

Button bush (*Cephalanthus occidentalis*) : 4–10 feet ; white ; summer ; flowers in globular heads, fragrant ; good for planting in wet places.

Chokeberry (*Pyrus arbutifolia*) : 3–8 feet ; pinkish ; early summer.

Cinquefoil, shrubby (*Potentilla fruticosa*) : 1–3 feet ; yellow ; early summer ; foliage grayish ; does well in dry situations.

Coralberry (*Symphoricarpos vulgaris*) : 2–4 feet ; pink ; summer ; fruit coral red ; plant desirable for dry banks ; spreads by stolons.

Crab, wild (*Pyrus coronaria*) : 8–15 feet ; pink ; early summer ; fruit fragrant, hard, and sour ; used for preserves.

Cranberry, high-bush (*Viburnum opulus*) : 6–12 feet ; white ; late spring ; fruit red, persistent ; regarded as the parent of the snowball tree.

Currant, flowering (*Ribes aureum*) : 4–8 feet ; yellow ; early spring ; flower very strongly spicy-scented ; fruit black.

Currant, wild (*Ribes floridum*) : 3–7 feet ; greenish ; early spring.

Daphne (*Daphne mezereum*) : 1–4 feet ; rose-purple or white ; early spring ; flowers appear before the leaves.

Deutzia (*Deutzia scabra*) : 4–6 feet ; white ; late spring ; leaves sprinkled with stellate hairs.

Deutzia, small (*Deutzia gracilis*) : 2–3 feet ; white ; spring ; much used for low borders.

Dogwood, or red osier (*Cornus stolonifera*) : 4–8 feet ; white ; early summer ; stems dark red, very showy in winter ; spreads by stolons.

Elder, common (*Sambucus Canadensis*) : 6–12 feet; creamy white; early summer ; valued alike for its large panicles of flowers and for its purplish-black fruit ; medicinal ; several variegated and cut-leaved forms are known.

Elder, red-berried (*Sambucus pubens*) : 6–10 feet ; greenish ; spring ; berries bright red, ripening in early summer at the time the preceding species is blooming ; several cut-leaved forms are cultivated.

Fringe tree (*Chionanthus Virginica*) : 7–10 feet ; white ; spring.

Golden bell (*Forsythia suspensa*) : 6–8 feet ; bright yellow ; early spring ; flowers appear before the leaves and cluster thickly along the branches ; one of our most decorative species ; branches drooping.

Golden bell (*Forsythia viridissima*) : 6–12 feet ; yellow ; early spring ; more erect than the preceding.

Gooseberry, early (*Ribes gracilis*) : 3–6 feet ; pale yellow ; early spring ; the first shrub to put forth leaves in spring ; thorny ; much used for hedges.

Hardhack (*Spiræa tomentosa*) : 1–3 feet ; pink ; summer.

Hawthorn (*Cratægus* sp.) : 10–15 feet ; white ; spring.

Hazel (*Corylus* sp.) : 6–12 feet ; yellow and red ; early spring ; the flowers are borne in catkins and are among the first to appear in spring ; the fruit is the well-known filbert.

Honeysuckle, Tartarian (*Lonicera Tatarica*) : 6–10 feet ; pink ; late spring ; red berries.

Hop tree (*Ptelia trifolia*) : 6–12 feet ; greenish ; early summer ; flowers sweet scented ; fruits round, broad-winged.

Hydrangea (*Hydrangea paniculata*) : 4–8 feet ; white ; summer.

Jersey tea (*Ceanothus Americanus*) : 1–3 feet ; pale cream ; early summer ; excellent for dry places ; the feathery flower clusters are borne in profusion ; seeds are thrown long distances by the splitting of the pod ; the young seed pods contain much vegetable soap.

June berry (*Amelanchier* sp.) : 6–20 feet ; white ; early spring ; fruit red or blackish, sweet, and edible.

Kerria (*Kerria Japonica*) : 3–5 feet ; orange-yellow ; early summer ; twigs bright green in winter.

Kerria, white (*Rhodotypus kerrioides*) : 3–6 feet ; white ; early summer.

Laurel, mountain (*Kalmia latifolia*) : 2–8 feet ; pinkish ; early summer.

Leadwort (*Amorpha fruticosa*) : 4–6 feet ; purplish ; summer.

Leatherwood (*Dirca palustris*): 3–6 feet; yellow; early spring; excellent for wet places; flowers appearing with the leaves; bark exceedingly tough.

Lilac, common (*Syringa vulgaris*): 8–15 feet; purple or white; early spring.

Lilac, Persian (*Syringa Persica*): 8–15 feet; purple; spring; more spreading than the preceding species.

Ninebark (*Physocarpus opulifolius*): 6–12 feet; white; early summer; flowers like those of the spiræas; bark shed in long strings; medicinal.

Olive, Russian (*Elæagnus angustifolius*): 8–15 feet; cream color; early summer; leaves silvery white from the numerous scales; fruit silvery.

Osier, European (*Cornus sanguinea*): 4–8 feet; white; early summer; stems deep red; a form with white-edged leaves is common.

Pea bush (*Desmodium penduliflorum*): 4–5 feet; rose-purple; autumn.

Pea tree, Siberian (*Caragana arborescens*): 10–15 feet; yellow; spring.

Pearl bush (*Exochorda grandiflora*): 6–12 feet; white; spring.

Privet (*Ligustrum* sp.): 4–12 feet; white; summer; nearly evergreen; the various species are much used for hedges.

Quince, Japanese (*Cydonia Japonica*): 6–10 feet; bright red; early spring; flowers appearing with the leaves; shrub thorny.

Raspberry, flowering (*Rubus odoratus*): 2–5 feet; purple; summer; thornless; leaves large, lobed; fruit insipid.

Rhododendron (*Rhododendron* sp.): 6–12 feet; white to pink; summer.

Rose of Sharon (*Hibiscus Syriacus*): 8–12 feet; white to red; late summer; very attractive, the flowers like hollyhocks.

Senna, bladder (*Colutea arborescens*): 8–10 feet; yellow; early summer; pods inflated.

Sheepberry (*Viburnum lentago*): 6–12 feet; white; summer; fruit black, edible.

Silver bell (*Halesia tetraphylla*): 8–15 feet; white; spring; the bell-shaped flowers are succeeded by curious four-angled and winged fruits.

Smoke tree (*Rhus cotinus*): 8–15 feet; greenish; spring; the smoke-like masses regarded by many as flowers are really flower stalks.

Snowball, Japanese (*Viburnum plicatum*): 6–10 feet; white; early summer; the flower clusters consist of sterile flowers, and the whole plant resembles the common snowball, or guelder-rose.

Snowberry (*Symphoricarpos racemosus*): 2–5 feet; pink; summer; fruit white, persisting into the winter.

Spicebush (*Benzoin odoriferum*): 6–10 feet; yellow; early spring; flowers appear with the leaves; bark spicy.

Spiræa (*Spiræa* sp.): 6–8 feet; white; early summer; the various species of spiræa are among our most decorative plants.

Spiræa, blue (*Caryopteris mastacanthus*): 2–4 feet; bright blue; late summer; has the appearance of a spiræa, whence the common name.

Sumac, common (*Rhus glabra* and *R. typhinia*): 5–15 feet; greenish; early summer; foliage turns brilliant crimson in autumn; fruits acid, edible; several cut-leaved varieties occur.

Sumac, fragrant (*Rhus aromatica*) : 3–6 feet ; yellow ; spring ; flowers in catkins appearing before the leaves ; fruits red, edible.

Sumac, varnish (*Rhus copallina*) : 3–6 feet ; greenish ; summer ; leaves brilliant red in autumn ; good shrub for dry places.

Sweet shrub (*Calycanthus floridus*) : 3–8 feet ; brownish-purple ; late spring ; flowers very fragrant when wilted, and of an unusual color.

Syringa, mock orange (*Philadelphus coronarius*) : 6–10 feet ; cream color ; late spring ; flowers very fragrant ; several other species are cultivated.

Tamarisk (*Tamarix* sp.) : 10–15 feet ; pinkish ; summer ; flowers and leaves small ; branches wandlike.

Weigela (*Weigela rosea*) : 4–6 feet ; rose color ; summer.

Willow, goat (*Salix caprea*) : 6–10 feet ; yellowish ; spring ; has immense catkins of flowers that appear in earliest spring.

Winterberry (*Ilex verticillata*) : 3–8 feet ; white ; summer ; a hardy deciduous holly with red berries that last through the winter ; excellent for wet places.

Witch hazel (*Hamamelis Virginiana*) : 6–12 feet ; yellow ; late autumn ; blooms as the leaves are falling ; seeds propelled for long distances ; plant much used in medicine.

FIFTEEN WOODY VINES DESIRABLE FOR ARBORS AND PORCHES

Bittersweet (*Celastrus scandens*) : twiner ; capsules orange-yellow, splitting at maturity and showing the scarlet arils.

Clematis, panicled (*Clematis paniculata*) : climbs by twining leafstalks ; flowers white, borne in great profusion.

Clematis, purple (*Clematis lanuginosa*) : climbs like the preceding ; flowers large, purple, very showy.

Creeper, trumpet (*Tecoma radicans*) : half twiner ; flowers large, tubular, dull orange-red ; seeds winged.

Dutchman's pipe (*Aristolochia macrophylla*) : twiner ; flowers shaped like a pipe ; leaves large, making a dense shade.

Grape, wild (*Vitis* sp.) : tendril climbers ; any of the wild grapes are desirable for covering arbors and trellises ; fruit makes excellent jelly and wine.

Honeysuckle, Hall's (*Lonicera Halliana*) : twiner ; flowers white turning yellow, very fragrant.

Honeysuckle, trumpet (*Lonicera sempervirens*) : twiner ; flowers long, slender, trumpet shaped, scarlet.

Ivy, Boston (*Ampelopsis tricuspidata*) : tendril climber, holding fast by small disks at the tips of the tendrils ; will cling to walls of any kind.

Matrimony vine (*Lycium vulgare*) : half twiner ; stem thorny ; flowers purplish ; fruit red, inedible.

Rose, climbing (*Rosa* sp.) : climbing by means of recurved prickles ; several species are useful for covering arbors, pillars, and porches.

Virgin's-bower (*Clematis Virginiana*): climbing by twining leafstalks; flowers numerous, white; fruit with downy appendages.

Wistaria (*Wistaria Sinensis*): twiner; flowers blue or white in large clusters, very showy.

Woodbine, common (*Ampelopsis quinquefolia*): tendril climber; fruit bluish-black, inedible.

Woodbine, Western (*Ampelopsis Engelmanni*): like the common woodbine, but tendrils tipped with disks that cling closely to supports of all kinds.

FIFTY DESIRABLE HERBACEOUS PERENNIALS

Aconite (*Aconitum napellus*): 3-4 feet; deep blue; summer.

Amsonia (*Amsonia tabernæmontana*): 2-3 feet; blue; early summer.

Aster, New England (*Aster Novæ-Angliæ*): 3-6 feet; purple or pink; autumn.

Baby's breath (*Gypsophila paniculata*): 2-3 feet; white; spring.

Baptisia (*Baptisia australis*): 2-3 feet; blue; early summer.

Beardtongue (*Pentstemon* sp.): 2-3 feet; white to red; summer.

Bellflower, Chinese (*Platycodon grandiflorum*): 2-3 feet; blue or white; summer.

Black-eyed Susan (*Rudbeckia triloba*, *R. hirta*, and *R. speciosa*): 1-3 feet; yellow and black; summer and autumn.

Blanket flower (*Gaillardia aristata*): 1-2 feet; red and yellow; summer and autumn.

Bleeding heart (*Dicentra spectabilis*): 2-3 feet; pink; early spring.

Bluebells (*Mertensia Virginica*): 2-3 feet; sky blue; spring.

Boltonia (*Boltonia asteroides*): 4-5 feet; white; early autumn.

Butterfly weed (*Asclepias tuberosa*): 1-2 feet; orange-yellow; summer.

Columbine (*Aquilegia* sp.): 2-3 feet; white to yellow and blue; spring.

Coneflower, purple (*Echinacea purpurea*): 2-3 feet; purplish-red; summer.

Coreopsis (*Coreopsis* sp.): 2-3 feet; yellow; summer.

Dame's violet (*Hesperis matronalis*): 1-2 feet; white to pink; spring.

Golden glow (*Rudbeckia laciniata*): 6-7 feet; yellow; late summer.

Goldenrod (*Solidago rigida* and others): 3 feet; yellow; late summer.

Harebell (*Campanula Carpathica*): 6-9 inches; deep blue; summer.

Hollyhock (*Althæa rosea*): 3-8 feet; white to red and yellow; summer.

Iris (*Iris* sp.): 1-3 feet; white to yellow and purple; spring.

Jacob's ladder (*Polemonium* sp.): 1-2 feet; blue; spring.

Larkspur (*Delphinium formosum*): 1-3 feet; deep blue; summer.

Lilies (*Lilium* sp.): 2-4 feet; white to yellow and red; summer.

Lilies, day (*Hemerocallis* sp.): 2-4 feet; orange, golden yellow, and dull red; late spring and summer.

Lily of the valley (*Convallaria majalis*): 6-9 inches; white; early spring.

Lily, plantain (*Funkia* sp.): 1-1½ feet; white or blue; summer.

Marsh mallow (*Hibiscus moscheutos*): 4-6 feet; white and pink; late summer.

Mullein (*Verbascum pannosum* and *V. nigrum*) : 3–6 feet; yellow; early summer.

Obedient plant (*Physostegia Virginica*) : 2–3 feet; pinkish; summer.

Oxeye (*Heliopsis lævis*) : 2–3 feet; copper-yellow; summer.

Pea, perennial (*Lathyrus latifolius*) : 3–6 feet; pink or white; summer.

Peony (*Pæonia officinalis*) : 2–4 feet; white to red; late spring.

Pheasant's eye (*Adonis vernalis*) : 6–9 inches; yellow; early spring.

Phlox, perennial (*Phlox* sp.) : 2–3 feet; white to red and purple; summer and autumn.

Pink moss (*Phlox subulata*) : 6 inches; pink; spring.

Poppy, mallow (*Callirhoe involucrata*) : 6–9 inches; rose-pink; summer.

Poppy, perennial (*Papaver orientale*) : 2–3 feet; red; early summer.

Primrose, evening (*Œnothera* sp.) : 1–3 feet; yellow or white; summer.

Pyrethrum (*Pyrethrum hybridum*) : 1–3 feet; white to pink; spring.

St.-John's-wort (*Hypericum ascyron*) : 2–3 feet; yellow; early summer.

Senna, wild (*Cassia Marylandica*) : 3–6 feet; yellow; summer.

Sneezeweed (*Helenium autumnale*) : 3–6 feet; yellow; summer.

Sunflower (*Helianthus* sp.) : 6–10 feet; yellow; late summer and autumn.

Sweet flag (*Acorus calamus*) : 2–3 feet; green; summer.

Sweet William (*Dianthus barbatus*) : 1–2 feet; white to pink; summer.

Sweet William, wild (*Phlox divaricata*) : 1–2 feet; blue; late spring.

Yarrow (*Achillea ptarmica*) : 1–2 feet; white; early summer.

Yucca (*Yucca filamentosa*) : 3–6 feet; cream color; summer.

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ANNOUNCEMENTS

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